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SEPTOBASIDIUM IN THE UNITED STATES

By JOHN N. COUCH

PLATES 1-44

INTRODUCTION

In Burt's (1916) monograph of *Septobasidium* eight species were described from the United States. Later (1921) Snell added one to this number. The genus has been considered as tropical or subtropical and of rather rare occurrence. The writer has found, however, that the genus is in reality quite abundant in the southeastern states and has been able, through the collecting of other mycologists and several extensive collecting trips of his own, to add twenty-six species to the nine already known to occur in the United States. Of these twenty-six species, six have been described before from other parts of the world, while the remaining twenty are being described for the first time. Except for five of the species all have been studied in the fresh condition and only one species in the sterile condition has been described as new, *S. Peckii*, and this is such a distinct one that it can readily be separated by vegetative characters alone from all other known forms.

In view of the relatively large number of new species from this region and the increasing recognition of the importance of *Septobasidium* in forest pathology, it seemed that a separate publication in a form readily available to the mycologist or forest pathologist of the species which occur in this region would be worth while at this time. In a later publication, which will perhaps be ready in a few months, all known species are to be described and illustrated.

The distribution of the species of *Septobasidium* by states is shown in the accompanying table. The most extensive collecting trips have

TABLE 1

DISTRIBUTION OF SPECIES OF SEPTOBASIDIUM BY STATES AS  
INDICATED BY THE NUMBER OF COLLECTIONS

	Va.	N.C.	Tenn	S.C.	Ga.	Ala.	Miss.	Fla.	La.	Tex.	Ark.	Calif.	Pa.	N.J.	N.Y.	Canada	Total Collection
<i>S. alni</i>		several		9	1												15
<i>var. squamosum</i>				6													6
<i>S. apiculatum</i>	1	27		3			2	1	1								35
<i>S. canescens</i>													5				5
<i>S. carestianum</i>																7	7
<i>S. castaneum</i>		5		8	1	1	3	2	7								27
<i>S. cokeri</i>	1	18						2					1				22
<i>S. cremeum</i>								2									2
<i>S. curtisii</i>	2	60		14	6	2	2	6			3						95
<i>S. filiforme</i>	1	21															22
<i>S. fumigatum</i>				4	2			9	2								17
<i>S. fuscum</i>							1		1								2
<i>S. grandisporum</i>				1													1
<i>S. hesleri</i>			2														2
<i>S. langloisii</i>						6	13	2									21
<i>S. lepidosaphis</i>							2										2
<i>S. leprieurii</i>				3		5	4										12
<i>S. leprosum</i>	1	6		2				1									10
<i>S. lilacinae</i>		6		1													7
<i>S. mariani</i>	14	2	1					4	1								22
<i>S. patouillardii</i>	9		1				3	5									18
<i>S. peckii</i>													1				1
<i>S. pilosum</i>							1	1									2
<i>S. pinicola</i>		1										several	several				1*
<i>S. pseudopedicellatum</i>	4	30	2	4		1	14	12									67
<i>S. rugulosum</i>				2			3	1									6
<i>S. sabalis</i>								4									4
<i>S. sabal-minor</i>							1										1
<i>S. schweinitzii</i>		10		1													11
<i>S. sinuosum</i>		3	14			3	11	8									39
<i>S. sydowii</i>									1								1
<i>S. taxodii</i>									1								1
<i>S. tenuue</i>				1		5	3										9
<i>S. venosum</i>		40	2	1	1			1									45
Total species so far collected in each state	6	15	3	18	5	4	7	16	15	1	3	1	1	1	2	1	
	Va.	N.C.	Tenn	S.C.	Ga.	Ala.	Miss.	Fla.	La.	Tex.	Ark.	Calif.	Pa.	N.J.	N.Y.	Canada	

been made in North Carolina, South Carolina, Florida, and Louisiana and this fact might well explain the greater number of species from these states than from Georgia, Alabama, Mississippi, and Texas. It is quite likely that as more collections are made in these latter states the number of species from them will be greatly increased. Only four species are known to occur in the northern states, but no one has made an extensive search for the genus in that region.

The commonest of all species appears to be *S. Curtisi* which occurs on twenty-eight different species of trees, its most frequent hosts being *Nyssa sylvatica* and *Fraxinus americana*. The next most abundant is *S. pseudopedicellatum* which occurs on twenty-three different species of trees, its most frequent hosts being *Fraxinus americana* and *Carpinus caroliniana*. *Septobasidium sinuosum* has been found on fifteen different trees but is most frequently found on *Quercus nigra* and *Liquidambar styraciflua*. *Septobasidium castaneum* occurs on fourteen different trees, but is usually found on *Quercus phellos*. Other species show a less wide range in the choice of tree and several have been found on only one species of tree, as, for example, *S. canescens* on *Quercus agrifolia*, *S. Carettianum* on *Cornus stolonifera* (in this country), *S. grandisporum* on *Cornus florida*, *S. Schweinitzii* on *Fraxinus americana* and *S. sabalis* on *S. Deeringiana*, etc.

In my collections seventy-six different species of trees have been found to be subject to attack by *Septobasidium*. Of these seventy-six, some are very subject to attack by the fungal-insect combination. Eleven different species have been found on *Magnolia virginiana*, and *Liquidambar styraciflua*, ten on *Cornus florida*, nine on *Quercus nigra*, eight on *Cornus stolonifera*, seven on *Quercus phellos* and *Hicoria alba*. The trees most subject to attack, however, are not always the ones which harbor the greatest number of different species. The species most subject to attack are *Fraxinus americana*, *Nyssa sylvatica*, *Magnolia virginiana*, *Quercus phellos*, and *Q. nigra*. Many species of trees and shrubs appear to be free from attack by *Septobasidium* and others may be practically free, as *Fagus grandifolia*, *Tilia* spp., *Juglans*, and *Azalea* sp., on each of which only one single collection has been reported (Table 2).

Nineteen different species of scale insects have been found associated with *Septobasidium* in this region. The following table shows a partial list of species of *Septobasidium*, the scale insects with which they are associated and the host plants on which they occur.<sup>1</sup> Some species

<sup>1</sup> The scale insects have been identified by Dr. Harold Morrison, Bureau of Entomology, U. S. D. A., Washington, D. C.

TAB. 2  
HOST TREES OF SPECIES OF SEPTOBASIDIUM

	Host Trees of Septobasidium																			
Species of Septobasidium	Tess.	T. montana	T. tremulae	T. cordifolia	T. ciliata	T. mucronata	T. nigra	T. pumila	T. sibirica	T. tenuifolia	T. tremulae	T. tremuloides	T. virginiana	T. cordifolia	T. ciliata	T. mucronata	T. nigra	T. pumila	T. sibirica	T. tenuifolia
S. alni				1			1	3			1	2	1							
var. <i>squamosum</i>								1										1	2	
S. apiculatum			1	2	16	9			11			4	1			1			13	
S. burtii	2																			11
S. canescens																				10
S. carestianum						7														1
S. castaneum			1	1			2	1	1		3	2	2	1		1		3	7	1
S. cokeri	2						2	1	1									1	2	3
S. cremeum											1		1							2
S. curtisii				6		32	2	35	22	2	2	2	1	11	112	328	10	11	1	13321
S. filiforme	1		1	4	11	35	1	1						11			2			1
S. fumigatum	1	11				2	1													16
S. fuscum																			1	12
S. grandisporum							1													1
S. hesteri			2																	1
S. langloisi		10		7		2	2						12							35
S. lepidosaphis				113									1							5
S. leprieuri	1												9							2
S. leprosum				12	1	1	1		4											6
S. litschauicum							15													2
S. mariannii	2				23	2				1	2				1261		51		1	13
S. patouillardii						131		2												3
S. peckii		1																		1
S. pilosum											12								1	3
S. spinicola													12							1
S. pseudopeltatum	1	1	12	22	35	3	53	1	4		6	6	1		1		2	1	1	51
S. rugulosum											3	2					1			3
S. sabalis																		3		1
S. sabal-minor																			1	1
S. schweinitzii							10													1
S. sinuosum			11		3					1	7	3	3			11	9	4		412
S. sidowii																				1
S. taxodi																				1
S. stenue										5							4			2
Total species on hosts	12	3	12	1	1	12	7	12	22	30	16	2	6	3	7	4	2	15	14	11

TABLE 3

TABLE SHOWING PARTIAL LIST OF SPECIES OF SEPTOBASIDIUM, THE SCALE INSECTS WITH WHICH THEY ARE ASSOCIATED, AND THE HOST PLANTS

FUNGUS	INSECT	HOST PLANT
<i>S. Cokeri</i> .....	8394 <i>Aspidiotus osborni</i> 8395 <i>Aspidiotus juglans-regiae</i>	<i>Cornus florida</i> Same tree as above
<i>S. pseudopedicellatum</i> .....	8245 <i>Chionaspis gleditsiae</i> 8402 <i>Aspidiotus</i> sp. 8483 <i>Aspidiotus difflinis</i> 8461 <i>Aspidiotus juglans-regiae</i>	Ironwood Sweet gum Bay <i>Cornus florida</i>
<i>S. filiforme</i> .....	8263 <i>Aspidiotus aencylus</i> 8272 <i>Aspidiotus juglans-regiae</i> 8273 <i>Aspidiotus aencylus</i> 8237 <i>Chionaspis gleditsiae</i> 8273 <i>Aspidiotus juglans-regiae</i> 9077 <i>Aspidiotus forbesi</i>	New Jersey tea <i>Cornus florida</i> ; Same tree as above Ironwood Redbud Jap. quince
<i>S. pinicola</i> .....	11246 <i>Chermes</i> sp. apparently	White pine
<i>S. Curtisi</i> .....	8294 <i>Chionaspis sylvatica</i> 8457 <i>Chionaspis sylvatica</i> 8376 <i>Chionaspis gleditsiae</i>	Black gum Oak Ash
<i>S. grandisporum</i> .....	8465 <i>Chrysomphalus obscurus</i>	<i>Cornus florida</i>
<i>S. apiculatum</i> .....	8344 <i>Chrysomphalus tenebricosus</i> 8484 <i>Aspidiotus aencylus</i> 8484 <i>Aspidiotus difflinis</i> 8492 <i>Aspidiotus osborni</i>	<i>Cornus amomum</i> Same tree as above Sweet bay Pin oak
<i>S. leprosum</i> .....	8302A <i>Aspidiotus aencylus</i>	<i>Cornus florida</i>
<i>S. sinuosum</i> .....	8467 <i>Aspidiotus lataniac</i> (not typical) 8478 <i>Aspidiotus osborni</i> 8321 <i>Aspidiotus forbesi</i> 8466 <i>Aspidiotus osborni</i> 8316 <i>Aspidiotus juglans-regiae</i> 5934 <i>Aspidiotus liquidambaris</i> 5934 <i>Aspidiotus juglans-regiae</i> 4955 <i>Chionaspis gleditsiae</i>	Latex plant Water oak Amer. holly Oak Sweet gum Sweet gum Sweet gum Ironwood
<i>S. Schweinitzii</i> .....	8408 <i>Chionaspis gleditsiae</i> ? 8398 <i>Chionaspis gleditsiae</i> ? 8379 <i>Chionaspis gleditsiae</i> ?	Ash Ash Ash

TABLE 3—Concluded

TABLE SHOWING PARTIAL LIST OF SPECIES OF SEPTOBASIDIUM, THE SCALE INSECTS WITH WHICH THEY ARE ASSOCIATED, AND THE HOST PLANTS—Concluded

FUNGUS	INSECT	HOST PLANT
<i>S. alni</i> .....	8485 <i>Aspidiotus osborni</i>	Water oak
	8482 <i>Aspidiotus diffinis</i>	Sweet bay
	8481 <i>Aspidiotus osborni</i>	Willow oak
	8324 <i>Aspidiotus aencylus</i>	Hickory
	8325 <i>Aspidiotus liquidambaris</i>	Sweet gum
	8327 <i>Aspidiotus forbesi</i>	Amer. holly
	8323 <i>Chrysomphalus obscurus</i>	Willow oak
	8437 <i>Aspidiotus aencylus</i>	Pecan
	8479 <i>Aspidiotus liquidambaris</i>	Sweet gum
	<i>Aspidiotus uvae</i>	Sweet gum
<i>S. Patouillardii</i> .....	8396 <i>Chionaspis gleditsiae</i>	Ash
<i>S. castaneum</i> .....	8480 <i>Aspidiotus osborni</i>	Willow oak
	8453 <i>Aspidiotus juglans-regiae</i>	Black gum
	8451 <i>Aspidiotus osborni</i>	Oak
<i>S. Mariani</i> .....	8182 <i>Aspidiotus osborni</i>	White oak
	8447 <i>Aspidiotus forbesi</i>	Jap. quince
	8276 <i>Aspidiotus juglans-regiae</i>	Blue dogwood
	8377 <i>Aspidiotus juglans-regiae</i> (all 2nd stage)	Deciduous holly
	8400 <i>Aspidiotus juglans-regiae</i>	Sweet gum
<i>S. sabalis</i> .....	9151 <i>Aspidiotus (?) sabalis</i>	<i>Sabal Deeringiana</i>

as *S. sabalis*, *S. Schweinitzii*, etc., which occur on only one host plant are associated with only one species of scale insect. Other species which are found on a wide variety of host plants may be associated with several species of scale insects, e.g. *S. alni* and its variety *squamosum* are associated with seven different species. In some cases, as in *S. apiculatum* on *Cornus amomum*, as many as three different species of scale insects have been found under the same specimen, *Aspidiotus aencylus*, *Chrysomphalus obscurus*, and *Parlatoria proteus* but only individuals of the first were parasitized. *Septobasidium Curtissii*, which usually occurs on ash and black gum with *Chionaspis sylvatica*, may also parasitize species of *Aspidiotus*, as for example *Aspidiotus perniciosus*. From the results so far obtained it appears that the greater number of species of *Septobasidium* are not limited to an association with one scale insect but may be associated with several.

The size, structure and color characters in *Septobasidium* are of considerable diagnostic importance. The different species vary greatly in size, some being characteristically small and inconspicuous, as, for example, *S. sabal-minor*, *S. apiculatum*, *S. Hesleri*, *S. pilosum*, etc. Other species though forming small patches of growth may, because of the large number of patches formed, be quite conspicuous, e.g. *S. Burtii*. Other species form large and conspicuous patches of growth, e.g. *S. pseudopedicellatum*, *S. grandisporum*, *S. castaneum*, *S. sinuosum*, *S. Langloisii*, etc. Some species show a characteristic definiteness of shape and have a sharply delimited margin, while in other species the margin may be indeterminate and the outline of growth quite irregular. The thickness of the growth is also characteristic for the different species, some producing patches the top surfaces of which stand up from the bark as much as two or three millimeters, as, for example *S. grandisporum* or *S. fumigatum*; while other species may be so thin as to appear as mere discolorations on the surface of the bark, as, for example, *S. tenue*.

Just as the different species vary in size they also vary strikingly in the structure of the context. About half of the species described below show three distinct structural regions or layers. First the subiculum which is next to the bark and from which arises the second layer composed of vertical pillars or columns of hyphae. From the tops of the pillars arises the third layer which extends as a flat roof over the tops of the pillars. Some of the species with pillars have three horizontal layers: the subiculum, the top layer, and then another, incompletely formed layer parallel to these two and slightly raised above the subiculum. *Septobasidium pseudopedicellatum* and *S. Cokeri* are excellent examples of forms in which there are two horizontal layers and in which the pillars are very conspicuous. *Septobasidium Mariani* and *S. castaneum* illustrate types with three horizontal layers. The size and structure of the pillars vary greatly in the different species and are therefore of considerable diagnostic value.

The species in which pillars do not occur show such enormous variations in vegetative structure that space does not permit a detailed discussion.

In reproductive structures the various species show wide variation. All species so far found in the United States form basidia except two which apparently produce only conidia.

The basidia show eight distinctly different types as indicated in the list below. The probasidial cell may be present or absent. If present, it may persist as an empty cell at the base of the basidium or it may

elongate and become septate to form the basidium. The basidia may be one, two, three, or four-celled, straight or coiled. By far the commonest type is that with a straight, four-celled basidium with a persisting probasidial cell.

(1) Basidia 1-celled, with persisting probasidial cell.

*S. grandisporum.*

(2) Basidia 2-celled, without persisting probasidial cell.

*S. Patouillardii.*

(3) Basidia 2-celled, with persisting probasidial cell.

*S. sabalis*, *S. Langloisii*, *S. sinuosum*.

(4) Basidia 3-celled, without probasidial cell.

*S. apiculatum.*

(5) Basidia 3-celled, with probasidial cell.

*S. canescens.*

(6) Basidia 4-celled, without probasidial cell, basidia coiled.

*S. Schweinitzii*, *S. lilacinoalbum*, *S. Hesleri*, *S. rugulosum*, *S. tenue*.

(7) Basidia 4-celled, with probasidial cell, basidia straight.

*S. fumigatum*, *S. leporosum*, *S. Cokeri*, *S. Curtisi*, *S. lepidosaphis*, *S. alni*, *S. alni* var. *squamosum*, *S. Carestianum*, *S. Leprieurii*, *S. castaneum*, *S. Burtii*, *S. pseudopedicellatum*, *S. sabal-minor*, *S. pinicola*, *S. Mariani*, *S. fuscum*.

(8) Basidia 4-celled, with probasidial cell, basidia coiled.

*S. filiforme*, *S. taxodii*, *S. Sydowii*, *S. cremeum*.

All species which I have studied in detail, *S. Burtii*, *S. pseudopedicellatum*, *S. Cokeri*, *S. apiculatum*, *S. Schweinitzii*, *S. Patouillardii*, *S. filiforme*, *S. Curtisi*, and *S. lilacinoalbum*, are perennial. Such species undergo a regular cycle of development. In this region the probasidia are formed during late fall and winter, being mature and ready for germination in early spring. The probasidia germinate and the basidia are formed during wet weather throughout the spring and early summer. With the coming of spring, the fungus starts new growth, the growing continuing during the summer and early fall. In the greater number of species a new zone of growth appears around the margin. In some species in addition to a new marginal region of growth an entirely new top layer of growth may be formed over the old layer. Growth is characteristically slow in all species, amounting to only a few millimeters each season.

I have found in *S. Burtii* that the spores when mature are shot away from the sterigmata in the same manner as described by Buller (Researches, Vol. 2) for various Basidiomycetes. A small droplet of liquid suddenly appears at the spore-hylum. This droplet increases in size until it becomes about equal to one third the volume of the spore

and then suddenly the spore and droplet disappear. The spores are shot away so quickly that one cannot follow the course of one spore but one can see a single spore as it suddenly flicks across the field of view.

If the spore falls in a situation favorable for germination, as the moist surface of the bark or the moist surface of the fungus which bore it or on a slide in a damp chamber or on suitable culture media, it first becomes once, thrice, or many times septate. The number of septations in the spores seems in most species to be correlated with the number of septations in the basidium, i.e. the fewer septations in the basidium the greater the number of septations in the spore. After becoming septate the spore gives off bud cells as first described by Coker (Journ. E. M. Sci. Soc. **35**: 126. 1920). On nutrient agar the spores may, after a period of several weeks budding, give rise to mycelial threads. Some species, however, continue to produce bud cells on nutrient agar even after being in culture over a year. In culture all of the species which have been tested grow very slowly, producing after a year a circular area of growth only two or three centimeters wide. In none of the cultures so far have any reproductive structures appeared. A more complete report will be given on culture work later.

In nature the further fate of the bud cells is known only in *S. Burtii* (= *S. retiforme* of American authors). In this species the young insects when crawling about over the fertile surface of the fungus accidentally pick up the bud cells which germinate and enter the young insects' haemocoel. (Couch, Quart. Journ. Micros. Soc. **74**: 383-437. 1931). This appears to be the only way in this fungus by which infection occurs. Through such infected insects, old colonies are renewed and new colonies are established. Though the same symbiotic relationship appears to exist in all the other species which are associated with scale insects, I have so far been unable to determine how the young become infected in any species other than *S. Burtii*.

The haustoria within the parasitized scale insects are very highly specialized as to structure, being perhaps the most highly specialized haustoria in all the fungi. The type of haustorium has been found to be constant in any one particular species, even in the species of *Septobasidium* which are associated with several different species of scale insects and since haustoria are always present, while the reproductive structures are not, the structure of the haustorium is of great diagnostic value in separating species, and sometimes even in determining if a particular fungus belongs in the genus or not. Five types of haustoria have been recognized: (1) the glomerulus type, e.g. *S. pinicola*; (2) irregular, long

coil type, e.g. *S. pseudopedicellatum*,—commonest type; (3) regular coils connected by fine threads and spindle-shaped segments, e.g. *S. Burttii*; (4) tufts of hyphae composed of spindle-shaped segments connected by fine threads, e.g. *S. apiculatum*,—a common type; (5) threads composed of spindle-shaped segments which give rise to branches of the same structure but which coil, e.g. *S. fumigatum*.

It has also been found that the mode of connection between the haustoria within the insects and the external fungus is characteristic for certain groups of species. Four different types of connections have been found: (1) Connections passing through dermal pores; (2) through skin by the mouth; (3) through vaginal pore; (4) through anus, and sometimes through both anus and vaginal pore.

All species of *Septobasidium* which I have studied cause damage to the trees on which they grow, the damage being due not to the fungus directly but to the combination of fungus and scale insects. The one exception to this is *S. polypodii* which directly parasitizes the sori of a species of *Polypodium* and is not associated with scale insects. In such species as *S. apiculatum* where the growth covers a small area the damage is slight but in the greater number of species the growth may be quite extensive, in which case the damage is considerable. I have seen numerous small trees of *Fraxinus* and *Nyssa* killed outright by *S. pseudopedicellatum* and *S. Curtissii*. Large trees of both these genera may be heavily infected in which cases they are very unhealthy, showing many dead limbs. Types of wood injury are shown in several of the photographs (plates 3, 5, and 11).

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## SEPTOBASIDIUM Pat.

Fungus body usually resupinate but very variable; dry, crustaceous or spongy. In the commoner species composed of three regions: the subiculum which grows over the bark, the middle region composed of upright slender pillars or thick pillars or mounds or ridges of hyphae which support the top layer in which the hymenium is formed. In some species the context is more or less compact throughout. Threads septate, without clamp connections. Probasidial cell undergoing a long period of rest before germinating, or elongating immediately into the basidium; probasidial cell sometimes lacking. Basidium usually transversely septate into two, three, or four cells, rarely one-celled, straight or curved. Spores elliptic or bent-elliptic, colorless, becoming divided into two to many cells soon after formation and budding numerous sporidia if kept moist. Inhabiting the stems, branches, leaves, and sometimes the fruits of living woody plants and generally symbiotically associated with scale insects, some of which are parasitized, others of which are left to reproduce; but sometimes directly parasitic on plants

Widely distributed in the tropics and the warmer regions of the temperate zone.

## KEY TO SPECIES OF SEPTOBASIDIUM IN THE UNITED STATES

I. Color whitish to pale buff when fresh

- A. Fungus body large and conspicuous, up to 10 or more cm. in area
  - 1. Pure white throughout when fresh, becoming pale buff in old condition. Pillars conspicuous. Probasidial cell present, basidia straight, 4-celled.....*S. Cokeri* n. sp. p. 40
  - 2. White with a tint of lilac (summer condition), mummy brown with whitish margin (winter condition), pillars less conspicuous than above and becoming dark colored. No probasidia, basidia coiled, 4-celled.....*S. lilacinum* n. sp. p. 56
- B. Fungus body small and inconspicuous, less than 10 cm. in area
  - 1. Pure white when fresh, pale buff on aging, the top surface cut up into areas about 1 square mm. in extent. Pillars very inconspicuous. Probasidia present, basidia straight, 4-celled  
*S. leporinum* n. sp. p. 42
  - 2. Cream colored when fresh, becoming clay colored when old, subiculum white. Pillars very inconspicuous, surface smooth or cracked, context thin, up to  $225\mu$  thick, probasidia present, basidia coiled.....*S. cremeum* n. sp. p. 46
  - 3. White when fresh, becoming rich buff with splotches of olive due to presence of algal cells. No pillars, context homogeneous throughout. Probasidia present, basidia straight, 3-celled.  
*S. canescens* Burt. p. 62
  - 4. White when fresh and remaining white or becoming buff; context very thin, without pillars, but with mounds capped by one or more spines which are about 1 mm. high. No persistent probasidial cell, basidia 3-celled, straight  
*S. apiculatum* n. sp. p. 62

## II. Color buff to dark brown

A. Fungus body large and conspicuous, up to 10 or more cm. in area

1. Light buff to chestnut brown, with a smooth and shiny surface; pillars very conspicuous, straight, unbranched, dark brown, the subiculum white, probasidia present, basidia 4-celled, straight.....*S. pseudopedicellatum* Burt. p. 20
2. Buffy brown to dark brown, pillars conspicuous, branched and entangled, dark brown, often with conspicuous marginal rhizomorphs. Probasidia and basidia as above  
*S. Mariani* Bres. p. 16
3. Vinaceous buff to wood brown. Pillars less than 1 mm. tall, unbranched and inconspicuous. Probasidia present, basidia 2-celled. On leaves and petioles of *Sabal*. *S. sabalis* n. sp. p. 69
4. Rood's brown to clay color, surface shiny and smooth except for cracks and holes. No pillars but tufts of hyphae present in young regions. Probasidia and basidia as in *S. pseudopedicellatum* Burt.....*S. Leprieurii* Pat. p. 27

B. Fungus body usually smaller than 10 cm. in area

- a. Usually a millimeter or more thick
  1. Buffy brown or darker, with conspicuous radiating ridges and depressions, no pillars. Probasidia and basidia as above.....*S. Burtii* Lloyd. p. 22
  2. Dark brown in center, the surface strigose towards periphery, no pillars. On *Pinus strobus*.....*S. pinicola* Snell. p. 19
  3. Deep brown with a grayish surface, which is irregularly split by deep fissures. Context very compact, without pillars. Probasidia present, basidia 4-celled, coiled. Hymenium with characteristic straight paraphyses  
*S. Sydowii* n. sp. p. 47
  4. Deep brown, about Van Dyke brown. Surface with numerous, erect, densely arranged, anastomosing spines, which may present an irregular honey-comb surface or may be covered by a hymenial surface. Probasidia present. Basidia straight, 4-celled.....*S. lepidosaphis* n. sp. p. 35
- b. Usually less than 1 mm. thick
  5. Cream color to buffy brown or cinnamon brown, margin frequently irregular in outline, pillars present but very indistinct. On *Cornus stolonifera* in America. Probasidia present, basidia 4-celled, straight  
*S. Carestianum* Bres. p. 29
  6. Cinnamon brown to burnt umber, margin usually regular in outline, frequently with a lighter, yellowish marginal zone. Pillars present but less distinct than above. Usually on *Quercus* and *Hicoria* in America. Probasidia and basidia as above but basidia larger.....*S. alni* Torrend. p. 32
  7. Pale buff in young specimens with a wide whitish margin, becoming wood brown to army brown, sometimes with a dusky purplish tint in fresh material. Hymenium with

numerous very delicate, fragile threads with deep brown contents. Probasidia present, basidia coiled, 4-celled

*S. filiforme* n. sp. p. 49

8. Grayish brown, the top surface incompletely formed, thus presenting a flaky or squamose appearance. Pillars absent or very inconspicuous. Probasidia present, basidia straight.....*S. alni* var. *squamosum* n. var. p. 35
9. Tawny olive to sepia, context compact,  $60\text{--}250\mu$  thick, surface minutely retiform, margin fibrillose, basidia 4-celled, coiled, without probasidial cell...*S. rugulosum* n. sp. p. 59
10. Dirty Mars brown, sometimes concolorous with bark, very thin and difficult to distinguish. Probasidia present, basidia 4-celled, coiled. On *Taxodium*

*S. taxodii* n. sp. p. 48

11. Tawny to russet, top surface composed of flat, sinuose, anastomosing plates, in section  $500\text{--}1000\mu$  thick. Hymenium composed of compacted upright threads

*S. Peckii* n. sp. p. 75

12. Russet, spongy cottony in texture, on fruits of *Sabal minor*

*S. sabal-minor* n. sp. p. 19

### III. Color gray or grayish brown to slate gray to grayish lavender

- A. Fungus body large and conspicuous, more than 10 cm. in area

1. Smoky gray, the hymenium about mouse gray, the sterile parts about mummy brown or nearly black on *Cornus*. In section  $600\text{--}1400\mu$  thick, no pillars. Probasidia present. Basidia 4-celled, straight. Usually on *Acer* sp....*S. fumigatum* Burt. p. 44
2. Violet plumbeous or grayish blue, top surface composed of sinuose plates or frequently cracked in old regions. Margin blackish with distinct rhizomorphs.....*S. Langloisii* Pat. p. 67
3. Pale mouse gray to purplish gray, surface with sinuose, anastomosing ridges the sides of which are rounded

*S. sinuosum* n. sp. p. 65

- B. Fungus body small and inconspicuous, less than 10 cm. in area

1. Mouse gray with brownish tint. Surface with minute ( $0.2\text{--}0.4$  mm. wide) darker colored elevated mounds. In section  $100\text{--}225\mu$  thick, compact. No probasidia, basidia coiled

*S. tenue* n. sp. p. 58

2. Pallid purplish gray to snuff brown. Surface flaky. Margin dotted with minute pillars. In section  $250\text{--}400\mu$  thick. No probasidia, basidia 4-celled, coiled....*S. Hesleri* n. sp. p. 54

### IV. Color brown with a purplish tint or nearly black

- A. Fungus body large and conspicuous, up to 10 cm. or more in area

1. Chocolate brown, nearly black when wet, surface smooth and shiny,  $1\text{--}1.5$  mm. thick. Margin with three horizontal layers. Pillars usually indistinct. Probasidia present, basidia 4-celled, straight.....*S. castaneum* Burt. p. 25
2. Nearly black with a purplish or bluish tint, sometimes fuscous,

200–400 $\mu$  thick, pillars usually inconspicuous. Probasidia with a roughened wall, basidia 4-celled, straight

*S. Curtistii* (B. & D.) B. & S. p. 37

3. Clove brown or Brussel's brown. In section 125–200 $\mu$  thick, no distinct pillars present. Probasidia present, basidia straight, 4-celled.....*S. fuscum* n. sp. p. 15
4. Sterile parts blackish brown, spongy, hymenium pale smoke gray, margin with distinct rhizomorphs, in section up to 2.5 mm. thick; basidia one-spored.....*S. grandisporum* n. sp. p. 72
5. Brownish with a purplish tint, with a smooth velvety surface. Margin finely fimbriate and with a whitish zone 2–4 mm. wide, without marginal pillars but with "pup-tent"-like structures. No probasidia, basidia 4-celled, coiled

*S. Schweinitzii* Burt. p. 52

B. Fungus body usually less than 10 cm. in area

1. Blackish brown. Context compact. No probasidia or basidia seen but abundant, small, oval, thin-walled conidia  
*S. conidial form* n. Sp. (unpublished)
2. Blackish brown with a velvety appearance and purplish tint or sometimes even lighter to snuff brown. Pillars slender, subiculum tan. No persistent probasidial cell, basidia 2-celled  
*S. Patouillardii* Burt. p. 70
3. Deep brown, forming minutely setose, small patches 1–10 mm. wide. Septate, coiled conidia formed; no probasidia or basidia seen in American material.....*S. pilosum* B. & S. p. 73

### Septobasidium fuscum n. sp.

#### Plates 13 and 24

Fungus body resupinate, very closely adherent to the bark; covering areas equal to several hundred square centimeters; clove brown, fuscous or Brussel's brown (Ridgway). Surface characteristically smooth except for irregularities in the bark, minute holes and elevated patches of coarse, loosely entangled hyphae. Beneath each of these patches is a scale insect. Margin usually indeterminate, composed of branched threads. In section 125–200 $\mu$  thick, composed of three indistinct regions: (1) the subiculum, composed of a few branched threads about 4.2–5.8 $\mu$  thick, rarely up to 6.3 $\mu$  thick which adhere closely to the bark; (2) upright hyphae arising from the subiculum and branching out to form (3) the top layer; top layer 60–85 $\mu$  thick, composed of branched hyphae recurved at the tips, hyphae 2.2–3.5 $\mu$  thick, probasidia and basidia in various stages of development. Probasidium spherical or slightly subspherical, 10–12.6 $\mu$  thick, sprouting and emptying its entire contents to form a cylindrical 4-celled basidium which is 4.2–5.4 x 35–40 $\mu$ ; sterigmata 4–5 $\mu$  long. Spores 4–5 x 6–13.4 $\mu$ , bent-elliptic.

Symbiotically associated with *Aspidiotus diffinis* Newst., some of which are parasitized by very regular coils which are connected by ex-

tremely fine threads and spindle-shaped cells, as in *S. Burtii* Lloyd; other insects are free from parasitism and are in all stages of development.

This remarkable species has appeared only twice but because of its thin structure, it may be easily overlooked as a discoloration on the bark. It may be distinguished from other species by its thin structure, clove brown color, and by the minute elevated patches of hair-like hyphae which cover the scale insects. Microscopically it may be distinguished from all other species except *S. Burtii* by the very regularly coiled haustoria connected by fine hyphae and spindle-shaped cells.

Specimens examined:

Mississippi: Near Pascagoula, Jan. 1, 1932, with *Aspidiotus diffinis* Newst., J. N. Couch, coll., 9192. Type.

Louisiana: Near Baton Rouge, on *Quercus?* Dec. 31, 1931, J. N. Couch, coll., 9177. Differs from the type in being wood brown to Brussels' brown (Ridgway) and in the absence of the patches of loosely woven threads which cover the insects.

**Septobasidium Mariani** Bres. Ann. Myc. 1: 24. 1903. Diagnosis in Ann. Myc. 3: 164. 1905.

Sense of Bresadola and Patouillard, not Bourdot and Galzin.

Plates 4, 26, and 44

Fungus body perennial, resupinate, forming patches sometimes as much as 10 cm. long, often girdling the limbs. Composed of two distinct zones: (1) the older central part over which the hymenium has been formed and (2) the marginal region. Central region typically dark brown during the summer, becoming somewhat fleshy brown and later buffy brown in fall and retaining the lighter color until after the spore-bearing period in the spring. Surface of central region irregular and granulose in fall when forming, becoming smooth and shiny and finally becoming split by irregular cracks. Marginal region very distinctive and peculiar, deep brown in color (darker than central portion) except for the very narrow, outer, growing zone which is whitish; about 1 cm. wide in late summer, hardly over 2 mm. wide by late winter due to the formation of new hymenium; marginal region often higher than the central region, composed of a basal subiculum, over which extend numerous dark colored rhizomorphs. From the upper sides of the rhizomorphs plates of horizontal threads grow outward. Where the plates come in contact with each other, they fuse, thus forming a layer over the subiculum. This condition is distinct at the outer growing margin. From the older portion of the marginal region a vast tangle

of much branched and anastomosing pillars arise. The pillars branch out at the top giving rise to the hymenial surface. In section up to 2 mm. thick, stratose in older portions. In younger regions composed of (1) a basal subiculum which extends over the bark and over which numerous branched dark brown rhizomorphs extend, subiculum thin, about 25-30 $\mu$  thick; (2) a region of very short stout pillars which arise from the subiculum and which with the rhizomorphs support (3) an incompletely formed layer parallel to the subiculum (the scale insects are located between the subiculum and the second layer), space between subiculum and second layer about 100 $\mu$  high; the second layer and the rhizomorphs give rise to (4) the long, branched, slender, anastomosing pillars, often about 1 mm. tall, 15-60 $\mu$  thick, threads of pillars 3.8-4 $\mu$  thick, septate, without clamp connections, the pillars giving rise to (5) the top layer which bears the hymenium. Hymenium 50-90 $\mu$  thick, composed of rather compact, branched threads, 2.2-3.5 $\mu$  thick, from the sides of which the probasidia arise; probasidia pyriform, 6.7-8.4 x 10.9-18.9 $\mu$ , giving rise to a long, straight, cylindrical 4-celled basidium about 4.2-4.6 x 42-50 $\mu$ ; spores (no. 8400) bent-elliptic, white, 3.8-4.2 x 12.6-21 $\mu$ .

Symbiotically associated with several species of scale insects some of which are parasitized by irregular, coiled hyphae, others of which are left unparasitized. In this species the threads which connect the coiled haustoria of the fungus within the insect with the fungal pad which envelops the posterior part of the parasitized insect pass through either the anus, the genital pore, or through the thin cuticle by the mouth.

The most remarkable characteristic of this plant is that it is composed of three distinct stories: i.e., there is the basal subiculum (the first story) covering the bark, next a region of short, thick pillars and rhizomorphs and then another layer (the second story) parallel with the subiculum, and arising from this layer is a region of long branched pillars on the tops of which is borne the top layer (the third story). This characteristic can easily be recognized with a hand lens in material collected from mid-summer until early winter and serves to distinguish this species from all but a few species of *Septobasidium*. Another characteristic by means of which this plant may be distinguished is the peculiar marginal condition of plants collected in the late summer and early fall. At this time the new hymenium for the following year has not begun to develop and the new zone of growth between the margin of the old hymenium and the outer margin is composed of a dense tangle of dark colored pillars and rhizomorphs.

I have often found this species growing on the limbs along with typical *S. pseudopedicellatum* Burt and because of the similarity of color in some

lots of material the two plants may easily be confused, as has been done by previous students. Typical *S. pseudopedicellatum* Burt is a rich, buffy brown color on top with much darker brown, usually straight, and unbranched pillars, and with a white subiculum. (For further distinctions between this species and *S. pseudopedicellatum* Burt, see under the latter species.)

This species like all the others which I have studied is distinctly perennial. We have collections from around Chapel Hill during every month in the year. Moreover I have kept several specimens on *Pyrus japonica* marked in the arboretum for several years. The fungus has a very different appearance in winter and spring from that in the summer and fall, so different, in fact, that one would almost certainly describe the forms collected during these two seasons as distinct species. It is only by keeping the same specimen under observation for several years that one may prove that such apparently distinct fungi are merely stages in the development of the same fungus.

Widely distributed and fairly common in some localities.

Specimens examined:

Italy: Near Rome, on *Pyrus communis*, 1902, Mariani, (Patouillard Herb., Harvard Univ., and N. Y. Bot. Gard. Herb.) Type or co-type.

Caucasus: Near Suchum, on *Pyrus communis*, July 1915, W. Siemaszko, 9954.

Brazil: Near Bono Principio, 1928, J. Rick, Farlow Herbarium, also U. N. C., 9358, sterile.

North Carolina: Chapel Hill, on *Pyrus malus*, 4157, and on *Quercus nigra*, part of 3936 large piece, four other collections on *Quercus*, 8182, 8378, 8405, 9708. On *Pyrus japonica*, eight collections; on *Cornus florida*, 8253, 8395, 9898; on *Cornus amomum*, 8276, 9113; on *Ilex decidua*, 8377; on *Liquidambar styraciflua*, 8400, 9332.

South Carolina: Society Hill, on *Pyrus angustifolia*, July 22, 1922, J. T. Rogers, U. S. D. A. Herbarium and U. N. C., 9955.

Tennessee: Sevierville, on *Acer* sp., L. R. Hesler, two collections (Univ. Tenn. Herb. 538 and 540), U. N. C., 9709 and 9710.

Louisiana: Opelousas, on *Crataegus*, April 16, 1932, C. L. Shear (U. S. D. A. Herb.) and U. N. C., 9707, on *Taxodium distichum*, April 16, 1932, P. R. Miller (U. S. D. A. and U. N. C. Herb.), near Baton Rouge, on *Crataegus*, Dec. 31, 1931, J. N. Couch, 9165 and 9173.

Arkansas: Near Little Rock, on *Quercus phellos*, April 12, 1933, Dow V. Baxter, 9376.

*Septobasidium pinicola* Snell. *Mycologia* 14: 55-60, pls. 11-13. 1922.

Plates 7 and 18

This species has been so fully described by Snell that I can add but little to his observations.

Fungus body resupinate, forming small (2-3 cm. in diameter) roundish patches in the angles of the limbs on *Pinus strobus*. Army to natal brown in the central part with a lighter buff-colored margin. Surface smooth at first but becoming strigose toward the marginal region, usually remaining smooth in the center. The margin 1-2 mm. wide and more or less smooth. In section 400-1500 mm. thick, lacunar, spongy, not distinctly divided into regions. Hyphae 3-7.1 $\mu$  thick, usually about 4.2 $\mu$  thick, much septate, without clamps, sometimes slightly constricted at the joints, walls of hyphae slightly thinner than usual in the genus. Probasidia borne over entire plant body in my specimens, usually globose, 14-16.8 $\mu$  thick but sometimes subglobose, 13-16 x 15-20 $\mu$ , hyaline, germinating and becoming entirely empty to form a cylindrical, 4-celled basidium 6-7.5 x 58-70 $\mu$ , sterigmata about 8 $\mu$  long. Spores 3-4.4 x 13-21 $\mu$ , bent-elliptic.

Associated with an aphid relative (*Chermes* sp.), some of which are parasitized by irregular hyaline coils, each coil being shaped like the glomerules of a kidney, while other insects are not parasitized.

Easily distinguished by its usual habitat on *Pinus strobus*, its color, small size, and general appearance.

Described from New England and New York where it appears to be common (Snell). For collection data from this region see Snell, 1922. It has also been collected in Pennsylvania several times by Overholts and at Highlands, N. C., August 4, 1931, by me. Also on *Pinus monticola* from Idaho, coll. by Weir. In Mo. Bot. Gard. Herb., U. N. C. Herb., and Snell Herbarium.

*Septobasidium sabal-minor* n. sp.

Plates 14 and 22

Fungus body forming small, brownish, cottony, resupinate growths on the stems, leaves, and fruits of *Sabal minor*. The patches on the fruit are from 3 to 10 sq. mm. in area and always surround the pedicel scar. Margin determinate, surface spongy. In section up to about 1 mm. thick, not composed of distinct regions. Threads of context 3.6-4 $\mu$  thick. Hymenium rather indistinctly set apart from the context, composed of sparingly branched hyphae, probasidia and basidia. Probasidium spherical to pyriform, 8.4-10.5 x 10-12 $\mu$ , frequently with an

enlarged subtending cell, germinating and emptying its entire contents to form the basidium. Basidium cylindrical, divided by three transverse walls into 4 cells,  $4-4.6 \times 33-42\mu$ . Sterigmata  $4-5\mu$  long. Spores bent-elliptic, no septate ones seen.

Associated with scale insects, *Aspidiotus (?) sabalis* Comst., some of which are parasitized by irregular coils. This species somewhat resembles *S. sabalis* in gross structure and resembles *S. alni* in the structure of the probasidia, basidia, and spores, but can easily be distinguished from both of these species.

Collected only once and then by Miss M. L. Bomhard on the fruits of *Sabal minor*, 15 miles north of St. Augustine, Fla., Nov. 20, 1933. Type in U. N. C. Herbarium 9719, and in U. S. D. A. Herbarium, Washington, D. C.

**Septobasidium pseudopedicellatum** Burt. Ann. Mo. Bot. Gard. 3: 327.  
1916.

Plates 10, 11, 27 and 35

Fungus body resupinate, forming small to very extensive, conspicuous, foliose crusts on the bark and leaves of a great variety of trees and shrubs. Individual patches of growth up to 15 or 20 cm. in greatest dimension. Color very variable: light buff, or pale, smoke gray to cinnamon brown or chestnut brown. Hymenial surface smooth and usually shiny even under a lens, sometimes cracked and wrinkled in old specimens, in certain young specimens before the hymenium is formed the surface may be velvety or alveolate. Margin usually determinate, varying in appearance at different times of the year, subiculum of margin typically whitish, sometimes buff. Marginal region usually conspicuously marked by numerous upright pillars; however, in some conditions the top layer may extend out even with the subiculum obscuring the marginal pillars. Margin of upper layer sometimes fimbriate. In section 0.7-1.5 mm. thick, composed of three distinct layers or regions: (1) the very thin whitish subiculum which extends over the bark, threads of subiculum  $3.4-4\mu$  thick, often covered with minute crystals; from the subiculum arise the pillars which compose the (2) middle region. Pillars simple or branched in the older parts, sometimes arising in concentric rows on the margin, erect, 0.5-1.2 mm. tall, usually about 1 mm. tall by about  $40-60\mu$  thick, composed of parallel, septate, mostly unbranched hyphae about  $3.7-5.5\mu$  thick; brownish with a tuft of whitish threads at the base, the white threads encrusted with minute crystals. The pillars branch out above to form (3) the top layer over which the hymenium is formed. Top layer stratose in old specimens by the formation of several hymenial layers; up to  $300\mu$  thick, composed of loosely packed, branched and entangled, brownish threads,  $3.7-5.5\mu$  thick; giving rise to the hy-

menium, which because of its densely packed and entangled, colorless paraphyses and probasidia is sharply differentiated from the underlying brownish threads, hymenium  $35-50\mu$  thick; paraphyses or sterile threads about  $4\mu$  thick at their origin and tapering down to about  $2\mu$  thick, wavy; probasidia usually subglobose or pyriform, sometimes globose,  $11.5-13.8 \times 16-22.2\mu$ , giving rise to a straight, cylindrical basidium,  $4.8-7 \times 37-70\mu$ , usually  $6 \times 60\mu$ , thickest in the middle or toward the distal end, usually with a long stalk from which it frequently separates at maturity. Sterigmata  $4-5\mu$  long, lateral or sometimes terminal on the end cell. New probasidia may sometimes be formed within the old ones, such secondary probasidia giving rise to smaller basidia, which bear small spores. Spores white in print, bent-elliptic,  $3.7-4.8 \times 16-23\mu$  (the few spores seen in the type material agree), rarely up to  $5 \times 30\mu$ , becoming 4-8-celled.

Associated with a variety of scale insects on the leaves and bark of many kinds of trees and shrubs (*Fraxinus* spp., *Alnus* spp., *Pyrus* spp., *Quercus* many species, *Cornus*, *Hicoria*, *Carpinus*, *Liquidambar*, *Nyssa*, *Gleditsia*, *Acer*, *Crataegus*, *Betula*, *Magnolia*, *Ilex*, *Citrus*, *Taxodium*, *Staphylea trifolia*, and other wild and cultivated genera). Some of the scale insects are parasitized by haustoria in the form of irregular coils; other insects are free from parasitism.

This species in its commonest and typical form may easily be identified by the buffy to cinnamon brown color of the top layer, and its smooth surface; the dark colored erect pillars with the tuft of whitish threads at their bases, and by the thin, whitish subiculum. The pillars are always quite distinct in this species and it is unfortunate that it has the name *S. pseudopedicellatum*. The hymenial characters are also distinctive. The hyaline elements of the hymenium contrasting strikingly with the brownish underlying tissue, the subglobose or pyriform probasidia, the cylindrical, 4-celled basidium with its short sterigmata, and the wavy, tapering, hyaline threads help one to recognize this fungus.

This species may be distinguished from *S. Mariani* Bres., with which it frequently occurs, by the densely crowded, branched and entangled pillars and the minute, dark colored, marginal rhizomorphs of the latter. *Septobasidium Mariani* also frequently has an extra horizontal layer between the subiculum and hymenium. The reproductive structures of the two fungi are similar.

Widely distributed throughout the southeastern United States, reported as far west as Wisconsin and as far north as New Jersey. Perhaps the commonest species of this region. Also occurring on *Citrus* in Brazil, perhaps imported into that country on diseased *Citrus* stock. Represented by sixty-seven collections in our herbarium.

## Specimens examined:

North Carolina: Common in piedmont and coastal regions.

Virginia: Near Roanoke, on *Carpinus*, April 21, 1931, C. L. Shear, 9940; near Burkeville, Va., July, 1928, on *Cornus*, *Liquidambar*, and *Hicoria*, J. N. Couch, coll.

South Carolina: Common in piedmont and coastal regions. Near Myrtle Beach, on *Cornus amomum*, Aug. 28, 1931, J. N. Couch, coll., 9090; also on *Fraxinus*, 9092; near Charleston, on *Cornus florida*, March 19, 1929, J. N. Couch, coll., 8483; St. Helena's Island, on *Magnolia virginiana*, March 21, 1929, J. N. Couch, coll., 8462.

Florida: Common as far south as Sebring, J. N. Couch, coll.; Gainesville, on *Acer rubra*, Knight, coll. (Herb. of the University of Florida, 9189); on *Fraxinus*, A. S. Rhoads and E. West, colls. (Herb. of the University of Florida); also two collections from Weber on *Fraxinus* (Herb. of the University of Florida, 9411 and 9413); on orange leaves, F. A. Wolf, coll.; Homestead, on *Citrus grandis*, Link, coll. (Herb. of the University of Florida, 9187); also on *Citrus sinensis* (Herb. of the University of Fla., 9186).

Brazil: Estado de Minas Gerais, Viçosa. On *Citrus*, referred to *S. albidum* in *Phytopathology* 23: 734-737, 1933. Albert S. Müller, coll. (Müller Herb., 44). Dr. Müller has very kindly supplied me with abundant material which is in fruit and agrees well with *S. pseudopedicellatum* Burt.

Campo Grande, Rio de Janeiro, abundant on stems, twigs and leaves of *Citrus*. June, 1934. Near Azevedo, coll. Dr. Silveira Grillio, comm. Referred to *S. albidum* (Estudo sobre *Septobasidium albidum* da Laranjeira. *Agronomia* 1: 265-276, 2 pls. 1930.)

**Septobasidium Burtii Lloyd.** *Mycological Notes* 7: 1286, fig. 2902, plate 296. 1924. *S. retiforme* of American authors but not of Patouillard.

### Plates 1 and 28

Fungus body resupinate, forming rather tough and hard, more or less circular patches of growth, varying from 0.1-15 cm. in diameter, sometimes even larger, the patches sometimes anastomosing so that large limbs or trunks of small trees may be almost covered by the fungus. Color typically brown, the younger parts drab, the older darker brown, frequently mottled with lighter and darker spots. In some specimens the color is grayish. Margin characteristically determinate and whitish during the growing season. Surface typically formed of branched ridges

which radiate in an irregular fashion from the center outwards. Between the ridges are valleys which are partially covered by thin flaps. The surface is also frequently marked by fairly distinct annual, concentric growth zones which are usually 2-3 mm. wide. The outer margin of the concentric growth rings are usually bordered by the above mentioned flaps. In section up to 2 mm. thick, composed of three regions: (1) the subiculum, forming a thin ( $35-60\mu$  thick), closely adherent mat of densely packed threads on the surface of the bark and from which arise (2) the numerous anastomosing ridges composed of compacted more or less upright hyphae (about  $4\mu$  thick) which give rise to and support the top layer. Between the ridges are tunnels which radiate back toward the center; (3) top layer which varies from a fraction of a mm. up to 1.5 mm. thick. The lower surface of the top layer is black. The entire layer is composed of compacted hyphae which are of rather uniform diameter, 3-4.2, usually about  $4\mu$  thick, branched and with frequent septa, extending in a more or less vertical direction. Threads throughout brownish except in the regions of new growth where they are hyaline. Hymenium formed over the top layer  $40-65\mu$  thick, composed during the fertile season of probasidia and basidia in various stages of development and recurved hyaline hyphae. Probasidia hyaline, subglobose, ovoid to pyriform, most frequently ovoid,  $8-12 \times 16-24\mu$ , sprouting to form a cylindrical, thrice septate basidium. Basidia usually with a long stalk  $8-15\mu$  long, pointed at the distal end, thickest in the middle, frequently separating from the stalk when mature,  $6-8 \times 50-65\mu$ . Each cell of the basidium gives rise to a short sterigma on the end of which is borne a spore. Spores usually dividing into four cells if kept in a damp chamber and then giving rise to numerous, minute, bud cells.

Symbiotically associated with scale insects (*Aspidiotus osborni* and sometimes *Chrysomphalus obscurus*), some of which are parasitized by haustoria in the form of very regularly coiled hyphae, each coil being connected by a fine thread; the coiled hyphae eventually connecting with hyphae composed of spindle-shaped cells joined by fine threads. Some insects are not parasitized and are to be found usually in all stages of development.

This species is quite distinct from *S. retiforme* (Berk. and Curtis) Pat. (Bull. Soc. Myc. Fr. 16: 55, 1900-no. 384 in Cuban Fungi represented by two collections, nos. 288 and 214, in the Kew Herbarium and Curtis Herbarium, one of which, No. 214, is not a *Septobasidium* but either a sterile lichen or blue green alga), as was first noted by Lloyd (1924). *Septobasidium Burtii* is usually predominantly drab with a dark brown center, while *S. retiforme* is cinnamon brown with a powdery gray sheen. The shape of growth also differs: in *S. Burtii* the growth is usually circular, in *S. retiforme* of irregular shape. The surface of *S. Burtii* is

reticulately veined, the veins are rounded and adjacent veins are connected by a rather thin layer of hyphae and thus the top layer forms a continuous covering except for numerous holes which are partly covered by flaps; thus the subiculum in *S. Burtii* is not exposed except at the margin. In *S. retiforme* the surface is also reticulately veined but the surface of the veins is somewhat flattened without rounded edges, and the subiculum between the veins is exposed. In texture *S. Burtii* is hard and tough while *S. retiforme* is soft and flocculent. Unfortunately no one has seen mature basidia in *S. retiforme* but in some of the pieces of No. 288 the probasidia have elongated to form immature twisted basidia, some of which have become once septate. The probasidia and basidia of *S. retiforme* are quite distinct from those of *S. Burtii*. Furthermore, in *S. retiforme* the hyphae are loosely packed and frequently curved somewhat circinately and extend upwards at an angle of about 45°; in *S. Burtii* the hyphae are closely packed, and more or less straight and vertical. The hyphae of *S. Burtii* are slightly thicker than those of *S. retiforme*. In section the thickness of *S. Burtii* is characteristically variable due to the elevated ridges and depressions, being up to 2 mm. thick; in *S. retiforme* the thickness varies from 250–400 $\mu$ . A very striking difference between the two fungi is in the haustoria. In a small fragment of *S. retiforme*, No. 288 from Patouillard's herbarium, one parasitized scale insect was found and upon soaking in KOH and then crushing, the haustoria were seen to be in the form of irregular coils as in *S. pseudopedicellatum*, thus proving beyond possibility of doubt that the fungus which has been called *S. retiforme* in the United States is quite distinct from the *S. retiforme* (B. & C.) Pat.

This species is easily recognized by its circular shape, tough, hard texture, drab color and reticulately veined surface.

It causes marked damage to infected trees, badly infected limbs being killed after three or four years. Numerous spraying experiments have been carried out with this fungus over a period of several years but the only satisfactory way of eradicating the fungus and insects is to prune the infected limbs.

Coker (1920) first found and illustrated the germinating probasidia, basidia, and spores. Other studies showing the symbiotic relationship between the scale insects and fungus in this species have been published by the writer (1929, 1931).

This is one of the commoner species of *Septobasidium*, having been reported from the District of Columbia southward into Florida and westward as far as Texas. It is such a common and distinct species

that I have taken only a few specimens on my collecting trips, hence my collection data give no conception of its abundance.

Specimens examined:

North Carolina: Near Chapel Hill, over forty collections during all seasons on *Quercus palustris*, *Q. phellos*, *Quercus* sp., *Liquidambar styraciflua*, *Acer saccharinum*, *Pyrus communis*, and other unidentified hosts; Smith Island, on *Quercus virginiana*, Dec. 28, 1921, J. N. Couch, coll., 5927.

South Carolina: Near Charleston on *Quercus nigra*, March 1930, J. N. Couch, coll. Near Springwood, on *Pyrus communis*, July 2, 1928, J. N. Couch, coll., 8737.

Georgia: Near Wrens, on *Quercus nigra*, March 11, 1932, J. N. Couch, coll., 9227.

Alabama: Near Auburn, on *Prunus*, 1897, Earle and Baker, colls. In New York Bot. Gard. Herb. A variety with nearly smooth surface.

Louisiana: Near St. Martinsville, 1890, Langlois, coll. (*Flora Ludoviciana*, No. 2233), in New York Bot. Gard. Herb. Apparently this is the collection seen by Patouillard and identified by him as *S. retiforme* (B. & C.) Pat. (*Bull. Soc. Myc. de Fr.* **16**: 55. 1900).

Brazil: Near Sao Paulo, on *Meliaceae*, Nov. 6, 1934, J. Rick, coll., 9894. Agrees with typical material except spores and basidia larger. Spores 4.2–5.4 x 21–29.4 $\mu$ ; basidia 8.4–9.2 x 50–63 $\mu$ .

**Septobasidium castaneum** Burt. *Ann. Mo. Bot. Gard.* **3**: 319. 1916.

Plates 3 and 25

Fungus body resupinate, growing in large patches and often covering an area equal to several square feet; not rarely extending in effused patches from the base of a tree nearly to the top. Chocolate brown when dry, becoming nearly black when wet. Surface typically smooth and shiny, sometimes with cracks or pin holes. Margin distinctly fimbriate, mostly concolorous with the surface except in rapidly growing specimens and then nearly white in the growing region, determinate; typically with stout or slender pillars from near the bases of which arise horizontal hyphae which extend out, anastomose at the tips forming a second layer parallel to the subiculum; from the tops of the pillars threads extend out horizontally forming the top layer; in the older parts this middle horizontal layer is usually quite indistinct. Thus there are three horizontal layers as in *S. Marianii*. Margin of top layer at times extending out over the margin of bottom layers; margin sometimes with

an irregular honeycomb appearance. In section 1–1.5 mm. thick, often stratose by the formation of several fruiting layers in old specimens; composed of three regions: (1) the subiculum made up of a compact layer of threads which grow over the surface of the bark, 30–50 $\mu$  thick; (2) the middle region which at first is composed of upright inconspicuous pillars or tufts of hyphae not grouped into pillars; pillars becoming indistinct as the fungus develops, the spaces between them being nearly filled by the growth of hyphae until in the older parts of specimens the middle layer is more or less continuous with the subiculum and top layer; (3) the hymenial layer which is about 30–40 $\mu$  thick and is composed of probasidial cells, basidia, and simple hyphae; probasidia usually subglobose, quite irregular in shape, the large functional cell frequently subtended by a somewhat smaller swollen sterile cell 10–14.7 $\mu$ , most about 12 $\mu$  thick, thick-walled, sprouting under proper conditions to form a cylindrical basidium; basidia 5–6.7 x 37–50 $\mu$ , becoming thrice septate, i.e. divided into four cells, each cell bearing a spore on short sterigma. Spores 3.8–4 x 11–14.2 $\mu$ , bent-elliptic, usually not becoming septate.

This species shows considerable variation in color shade even on the same host, but can be recognized and distinguished from the related species by the following combination of characters: deep brownish chocolate color, inconspicuous pillars, peculiar margin, and comparatively small spores which do not become septate. For a comparison with *S. Leprieurii* (Mont.) Pat., to which this species is most closely related, see under *S. Leprieurii*.

This is one of the commoner species of *Septobasidium*, being by far the commonest species in the eastern part of South Carolina, so far as my observations go. By far the commonest host is the willow oak (*Quercus phellos*). The worst infected trees are the young ones with trunks from one to five inches in diameter. The trunks of such trees are often nearly girdled with the fungus from near the base almost to the top. Such trees are very unhealthy, with numerous dead branches.

#### Specimens examined:

Alabama: Near Montgomery, Dr. R. P. Burke, Mo. Bot. Gard. Herb., 20421 (type) and 20693, part of type in Farlow Herb.

North Carolina: Near Beaufort, very abundant on *Quercus rubra*, *Cornus florida*, *Ilex opaca*; specimens on *Ilex* associated with *Aspidiotus forbesi* Johns, J. N. Couch, coll., Aug. 3, 1929, several specimens fertile; near Wilmington, on *Quercus virginiana*, Dec. 28, 1921, Couch and Grant, colls., 5932, sterile; near Magnolia on *Quercus* sp., A. C. Mathews, coll., 9969.

South Carolina: Near Cheraw, Pee Dee River swamp, abundant on

*Quercus phellos*, June 29, 1928, A. B. and J. N. Couch, colls., 8318; near Georgetown, on *Hicoria*, 8329; also on *Quercus phellos*, *Ilex opaca*, 8332 and 8330, *Magnolia virginiana*, 8331; on *Pyrus communis* in orchard, half dozen trees noted all infected, 8336; on *Nyssa sylvatica*, 8328; near Clemson College, on *Azalea* sp., Feb. 19, 1932, Mr. Lutken, coll., sent by G. M. Armstrong, 9225. Mr. Lutken reports that the fungus was abundant, killing entire plants.

Georgia: About 19 miles east of Valdosta, on *Quercus*, March 19, 1932, J. N. C., 9299.

Florida: Homestead, on *Albizia* sp., with *Aspidiotus herculeanus*, March 9, 1933, spores forming, Univ. Fla. Herb., 9024; also common on *Quercus* sp., *Liquidambar*, *Ilex*, and other species as far south as Sebring, J. N. Couch, coll. Gainsville, on *Quercus nigra*, Feb. 22, 1935, G. F. Weber and E. West, colls., Univ. Fla. Herb., 9966.

Mississippi: Near Pascagoula, on *Magnolia virginiana*, 9201, mixed with *S. Leprieurii* (Mtg.) Pat., not typical; on *Quercus*, 9208; on *Fagus*, 9182, Jan. 1, 1932, J. N. Couch, Coll.

Louisiana: Baton Rouge, on *Liquidambar*, Jan. 8, 1932, C. A. Brown No. 327, not typical, apparently a cross between *S. castaneum* and *S. Mariani*; near Madisonville, on *Quercus nigra*, C. A. Brown No. 320, typical; near New Orleans, several collections on *Cornus* and *Quercus*, J. N. Couch, coll., Dec. 31, 1931.

**Septobasidium Leprieurii (Mont.) Pat. Bull. Soc. Myc. Fr. 16: 54. 1900.**

#### Plates 2, 3, and 25

Fungus body resupinate, covering extensive areas, up to 10 or 15 sq. cm., on the bark of living trees. Bister, Rood's brown, or clay color to tawny olive (Ridgway). Surface inherently smooth and velvety but frequently with pin holes and numerous sinuous or anastomosing cracks due to the incomplete formation of the top layer; in old specimens the surface frequently becomes broken by numerous fissures. Margin determinate, in some specimens the margins of both the top and bottom layers end abruptly at the same place as in the type material, without pillars, but with irregular small (about 1 mm. wide) plates of hyphae which arise from the subiculum and grow upward and backward to unite with the margin of the top layer. These plates are partly supported by tufts of hyphae. In section 500-800 $\mu$  thick, frequently stratose due to the formation of more than one hymenial layer. Composed of three regions in the younger parts: (1) a subiculum from which

arise (2) the short, scattered, tufts of hyphae which in turn give rise to and support (3) the top layer. In the older parts the tufts of hyphae are inconspicuous, due to the growth of hyphae which more or less fill the space between the tufts. The middle region is thus composed of a spongy context. Hyphae of context brownish, septate, about  $4.2\mu$  thick. Hymenium  $33-44\mu$  thick, composed of recurved threads, and probasidia and basidia in various stages of development. Probasidia globose to pyriform, sometimes subtended by an enlarged cell,  $9-10\mu$  thick, giving rise to a cylindrical, 4-celled basidium  $4.2-4.6 \times 28-35\mu$ , probasidium remaining as an empty cell after the formation of basidia. Basidia usually falling away from probasidia, leaving a short stalk attached to the latter. Sterigmata arising laterally, one from each cell; spores small, bent-elliptic  $3.8-4 \times 11-13\mu$ , rarely becoming septate.

Associated with scale insects (*Aspidiotus diffinis*), some of which are parasitized by irregularly coiled hyphae.

Until studying the type of *S. Leprieurii* (Mont.) Pat., I have considered the present species as a hybrid form of *S. castaneum* Burt and have segregated it with the latter species. Unfortunately the type material of *S. Leprieurii* is sterile (I found one basidium, 4-celled, cylindrical,  $5 \times 33\mu$ ) but some of my collections (Nos. 8317, 9254) agree almost perfectly with the type in color and vegetative structure. The type material is bister to Rood's brown with a smooth shiny surface. There are no pillars but only short tufts of hyphae toward the margin. These tufts can only be seen by turning over the top layer. The margins of both top and bottom layers end abruptly at the same place as in some of my specimens. In the older regions the context is composed of loosely packed hyphae and is stratose in places by the formation of more than one hymenial layer. Hyphae of type about  $4.2\mu$  thick. From the similarities in appearance and vegetative structure of the type of *S. Leprieurii* and the present species it is almost certain that they are the same but this can only finally be decided by the collection of fertile material of *S. Leprieurii* from the type locality.

The present species is very closely related to *S. castaneum* but may be distinguished from that species by the larger size, thicker structure, darker color, and larger probasidia, basidia, and spores of the latter. Typical *S. castaneum* is chocolate brown with a faint tint of purple, while *S. Leprieurii* is bister or Rood's brown, sometimes almost clay color. The marginal conditions of the two plants are also very distinct. In *S. castaneum* there are pillars on the margin and usually three horizontal layers are evident towards the margin, while in *S. Leprieurii* no pillars are evident and there are only two horizontal layers near the

margin. Also in *S. castaneum* the marginal region is frequently distinctly fimbriated or sometimes fibrillose, while in *S. Leprieurii* the margin is smooth or indistinctly fimbriate, except with a lens. The two species occur in the same region but usually on different trees, *S. castaneum* most frequently being found on *Quercus*, while *S. Leprieurii* is usually on *Magnolia virginiana*. In one of my collections on *Magnolia virginiana*, however, both species occur, in some places actually growing intermingled.

Specimens examined:

Guiana: Perhaps type, in Patouillard Herbarium, Harvard Univ.

Guadalupe: Near San José, on *Erythrina*, May 1915, Condert, coll.

There are two species in this material. The black one is *S. Curtissii* (not typical) and the chocolate brown one is perhaps *S. Leprieurii*. In color this resembles *S. castaneum* Burt but its very thin structure and lack of pillars suggest *S. Leprieurii*; another collection from the same locality on one of the Loranthaceae, May 1909, No. 151, is quite distinct from the type material of *S. Leprieurii*, in Pat. Herb. at Harvard Univ.

South Carolina: Near McBee, on *Magnolia virginiana*, June 30, 1928, J. N. Couch, coll., 8317, fertile; near Bethune, on *Magnolia virginiana*, March 20, 1932, J. N. Couch, coll., 9299, probasidia and basidia as in 8317, clay color.

Florida: Near Homestead, on *Albizia* sp., with *Aspidiotus herculeanus*, March 9, 1933, O. D. Link coll., Univ. of Fla. Herb., 9024, U. N. C., 9362; near Avon Park on *Magnolia virginiana*, March 13, 1932, J. N. Couch, coll., 9254; near Kissimmee, March 13, 1932, J. N. Couch, coll., 9238.

Mississippi: Pascagoula, very common on *Magnolia virginiana*, Jan. 1, 1932, J. N. Couch coll., Nos. 9184, 9188, 9201 (with *S. castaneum*), 9205, 9207.

**Septobasidium Carestianum** Bres. *Malpighia* 11: 16. 1897.

Plates 6 and 20

This species has been collected in the western hemisphere only by Dr. John Dearness in Canada and by Padre J. Rick in Brazil.

Fungus body perennial, resupinate, covering an area of several (2-6) square centimeters on the bark of living shrubs and trees. Color quite

variable: about cream color in young specimens, becoming buffy brown and sometimes cinnamon brown. Surface inherently smooth but often with minute pin holes or irregular fissures due to the incomplete formation of the top layer, the latter condition being particularly noticeable in young specimens. Margin determinate or often indeterminate and irregular in outline due to the formation of isolated patches of hymenium. In section 250–700 $\mu$  thick, often stratose, the primary stratum usually composed of three indistinct regions (in old, well developed specimens the subiculum, middle region, and top layer may be continuous): (1) the subiculum, usually exceedingly thin, hardly exceeding 10–15 $\mu$  thick in young specimens, in older specimens 30–60 $\mu$  thick, very compact, hyphae of subiculum about 3–4 $\mu$  thick, minutely rough; (2) the middle region which is composed of loosely packed, ascending, septate, pale or nearly hyaline hyphae about 3–4 $\mu$  thick without clamp connections and arranged in short cone-shaped tufts or in thick short pillars, the hyphae passing into and forming (3) the top layer over which is formed the hymenium; top layer 110–210 $\mu$  thick, composed of branched septate hyphae, hymenium sharply demarcated from the top layer by a region of densely packed, entangled, darker colored threads at the base of the hymenium, usually 35–40 $\mu$  thick but often up to 170 $\mu$  thick in old specimens, hymenium at first composed of hyaline, loosely packed, slightly curved threads, 2–3 $\mu$  thick, and irregularly arranged probasidial cells, in old specimens exceedingly compact, composed of densely packed threads, probasidia, and irregular branched cells which perhaps are probasidia which failed to germinate normally. Probasidia usually with a distinct stalk, often borne in clusters, usually pyriform, 6–8 x 11–14 $\mu$ , germinating to form a club-shaped basidium which is thickest at the distal end. Basidia 4.2–5 x 33.6–47 $\mu$ , 4-celled. Spores about 4 x 14.7 $\mu$ , bent-elliptic (only a few seen).

Associated with *Chionaspis corni* Cooley, some of which are parasitized by irregularly coiled hyphae, while others are left to reproduce.

In material collected in the fall, the healthy scale insects on the bark as well as beneath the fungus are exceedingly abundant. Beneath practically all the scales of the healthy insects there were vast numbers of eggs which are most likely intended for over-wintering. It would be interesting to see if the eggs unprotected by the fungus covering over-winter as well as those beneath the fungus. This insect has a comparatively thin scale and it is possible that eggs protected only by the scale could not resist either prolonged desiccation or severe freezings. Before it can be said that the insects receive any definite benefit from the fungus in the way of protection a prolonged series of observations must be made in the field.

Since the fungus does not penetrate at all into the bark of the dogwood, it appears to be entirely dependent upon the insects for its food

supply, drawing this indirectly from the shrub through the parasitized insects.

This fungus (Dr. Dearness, coll., 3396) was examined by Burt (1916) and placed under *S. pseudopedicellatum* Burt (Mo. Bot. Gard. Herb., 43802). The two plants, however, are very distinct in a number of ways and are easily separated by a casual examination. In *S. pseudopedicellatum* Burt the subiculum is white throughout, the pillars are dark colored, long and straight, unbranched, narrow, and are extraordinarily distinct, as distinct as in any species of *Septobasidium*. These characters, together with the reproductive organs, will serve to distinguish *S. pseudopedicellatum* Burt from *S. Carestianum* Bres.

The present species is very close to *S. alni* Torrend. In color characters *S. Carestianum* and *S. alni* may be separated, but only after an examination of a large amount of material representing all stages of development. The color of *S. Carestianum* is usually a lighter shade of brown than is that of *S. alni*, often being cream-colored. In *S. alni* the margin is usually determinate and sometimes (especially in specimens on pecan) the new growth region is a very distinct yellowish clay color as contrasted with the older dark brown region of growth, whereas *S. Carestianum* usually has a more or less indeterminate margin and shows no distinct color zones. Another important point of distinction is in the way in which the hymenia are formed in the two plants. In *S. alni* the hymenium as a rule extends almost out to the margin of the subiculum and does not show gaps and irregularities as in *S. Carestianum* in which the hymenium is incompletely formed in a number of areas during the period of growth. Microscopically the two plants are different in the size of the hyphae of the pillars and top layer and the size and shape of the probasidia and the size of the basidia and spores.

This plant is also related to *S. filiforme* but may easily be separated from that plant by the coiled basidia in *S. filiforme* and the presence of the abundant delicate threads with brownish contents in the hymenial region in the latter plant. In *S. Carestianum* there may be found a few threads in the upper layer with dark contents. Such threads are much thicker than the threads found in the hymenium of *S. filiforme*.

This plant may be distinguished by the thin fructification, the peculiar marginal characters, and the pyriform and frequently very irregular probasidia.

#### Specimens examined:

Italy: Type (?), on branches of *Salix*, 1897, part in N. Y. Bot. Gard. Herb.

Location ?: On *Salix incana* Schrank with *Chionaspis salicis* (L.) Sign., Aug. 15, 1917, Otto Jaap, indent., part in U. S. D. A. Herb. (V. Höhnel, 820).

France: Epinay, on *Cornus sanguinea* with *Chionaspis salicis*, July, 1906, in Patouillard Herb., Harvard University, spores present,  $3.8 \times 13.8\mu$ ; *S. Carestianum* Bres. forma *Fraxini* Pat., on trunk of *Fraxinus excelsior*, October, 1909; shows more distinct pillars but otherwise agrees with type.

Canada: North of London, Ontario, on living limbs of *Cornus stolonifera*, collected by Dr. Dearnness, 3396, Sept. 25, 1911, not in fertile condition, 9115; also July 10, 1929, 9116, fertile; August 23, 1929, 9117, no basidia found; November 11, 1929, 9118, not fertile; March 22, 1930, 9119, not fertile; Sept. 11, 1931, 9120, not fertile.

Brazil: Sao Leopoldo, Dec. 16, 1934, J. Rick, coll., in U. N. C. Herb., 9902, 9903.

*Septobasidium alni* Torrend. *Broteria, Ser. Bot.* 11: 84. 1913.

#### Plates 2 and 21

Fungus body resupinate, growing in medium sized patches, 2–10 x 3–20 cm., often girdling the limbs. Surface inherently smooth in mature specimens, becoming wrinkled and cracked when old; color, when fresh but dry, cinnamon to Prout's brown or Saccardo's umber; much darker, about burnt umber, when wet. Margin of growing region irregular, sometimes byssoid, whitish, buff colored or sometimes yellowish. In section up to  $400\mu$  thick, usually composed of three regions: (1) the subiculum or lower layer which extends over the bark, very compact, about  $30$ – $65\mu$  thick, composed of thin-walled, pale brown to nearly hyaline hyphae about  $3\mu$  thick; (2) the middle region composed of a very few, short, upright pillars between which are very wide spaces; pillars  $40$ – $100\mu$  tall, often up to  $175\mu$  thick, sometimes much thicker and not rarely as thin as  $20\mu$ , composed of brownish hyphae about  $4.2\mu$ , thick, pillars branching out above and forming (3) the more or less papery top layer on the outer surface of which is formed the hymenium, top layer  $200$ – $250\mu$  thick, composed of fairly densely packed, slightly branched and entangled hyphae which grow at a slight angle to the surface, hyphae deep brown in color except in the hymenial region, rather thick-walled,  $3.5$ – $4.2\mu$  thick. Threads throughout with few septa and no clamp connections. Hymenial region very thin (in my specimens), composed of thin-walled, slightly branched, nearly hyaline threads, probasidial cells, and basidia. Probasidial cells globose to subglobose, sessile,  $9$ – $12\mu$  thick before germinating, nearly hyaline and quite inconspicuous in the hymenium, probasidium sprouting into a long cylindrical basidium into which the probasidium empties its entire

contents, empty probasidial cell elongated ovoid or ellipsoid,  $8.8-10 \times 18-24\mu$ , thick-walled ( $1.5-2\mu$ ), new probasidia often formed in the old empty probasidial cells, elongated. Basidium  $5-5.4 \times 50-60\mu$ , becoming thrice septate, and thus four-celled, each cell giving rise to a sterigma about  $8\mu$  long. Spores (of No. 8325)  $3.4-4.2 \times 15.9-21\mu$ , smooth, bent-elliptic, becoming thrice septate, at times seven times septate soon after shedding.

Associated with scale insects some of which are parasitized by irregular coils while others are not parasitized.

This species shows remarkable similarities to *S. Cavarae* Bres. The American material has been compared with type material lent to me by Sydow (Torrend, No. 68) and the two lots of material agree in most respects. The type material does not show any basidia or spores, but does show vast numbers of empty probasidial cells and a considerable number of probasidia growing up into the older, empty probasidial cells. I have found more or less the same condition in my material collected during late summer, fall or winter. I am convinced that Torrend mistook these probasidia for the basidia, since the measurements which he gives for the basidia agree with the size of the probasidia found so abundantly in his material. He does not mention the probasidia, but concerning the basidia he says, "at first globose,  $10-12\mu$  in diameter, at length ellipsoid, 3-septate,  $20-25 \times 7-9\mu$ ; spores not seen."

This species can be recognized by the thin fructification, by the more or less papery top layer, by the few, inconspicuous, short, scattered pillars, which, however, cannot be seen well unless the top layer is removed and turned over, in which case the pillars adhere to the top layer; and by the buff colored margin, contrasting strikingly with the brown older region (this color is conspicuous only at the end of the growing season—late summer and fall). One remarkable peculiarity of this species is the fact that new probasidia are often formed within the old empty probasidial cells. Such probasidia are present in large numbers in regions of old growth in the late summer and fall and if a specimen bearing such probasidia is kept in a damp chamber, the latter will germinate, forming basidia. Another peculiarity, in some specimens, is the presence of numerous clusters of green algal cells imbedded here and there in more or less regular order just below the upper surface of the fungus. Delicate fungal threads often surround some of the algal cells and seem at places to penetrate into the cells.

In typical specimens of this species the pillars arise in a row from the subiculum, at first about one millimeter behind the growing margin.

These grow upward and quickly branch out at the top, developing first into an umbrella-like structure with a very short, thick stalk and an exceedingly wide, flat covering. After the subiculum has grown out a third or half a centimeter from the first row of pillars, another row arises and develops in the same way. The tops of the pillars grow in a horizontal direction until their margins come together and fuse. In the hybrid described below growth may stop before the margins all come together, thus leaving irregular spaces several millimeters wide between the margins. This condition gives the fungus a peculiar flaky appearance as though the top layer were peeling off. In my collections the flaky appearance is commoner in the sweet gum specimens, though it is also found in the willow oak, hickory, and American holly specimens. This flaky appearance has not been noticed on specimens occurring on pecan. In some specimens pillars may be entirely lacking in certain regions.

Fairly common in eastern North Carolina, South Carolina, Georgia, and probably in states farther south.

Specimens examined:

Portugal: Type, on *Alnus*, Torrend, coll. (373 in N. Y. Bot. Gard. Herb. and 68 in Sydow Herbarium now in Upsala).

North Carolina: Near Beaufort, on *Liquidambar*, Aug. 4, 1929, J. N. Couch, coll., 8415, common.

South Carolina: St. Helena's Island, J. N. Couch, coll., on *Quercus nigra*, with *Aspidiotus osborni*, March 21, 1930, U. N. C., 8485; on *Quercus phellos*, with *A. osborni*, U. N. C., 8481; on *Magnolia virginiana*, with *Aspidiotus diffinis*, U. N. C., 8482; Springwood, on *Q. phellos*, with *Chrysomphalus obscurus* Comst., July 2, 1928, J. N. and A. B. Couch, colls., U. N. C., 8323; on *Liquidambar*, with *Aspidiotus* (*Cryptophyllaspis*) *liquidambaris* Kot., U. N. C., 8325; on *Ilex opaca*, with *Aspidiotus forbesi*, U. N. C., 8327; on *Hicoria*, with *Aspidiotus aencylus* Putn., 8324; near Clemson College, on *Hicoria pecan*, with *Aspidiotus aencylus* Putn., Feb. 20, 1930, Geo. M. Armstrong, coll., U. N. C., 8437, also Nov. 24, 1930, U. N. C., 8556.

Georgia: Barnesville, on *Hicoria pecan*, common, Oct. 14, 1930, B. B. Higgins, U. N. C., 8498, fertile.

Venezuela: Carabobo, Valencia, 430 meters, on *Citrus sinensis*, Chardon and Stelling, 806, August 6, 1932, also in U. N. C. Herb. and L. O. Overholts Herb.

**Septobasidium alni** var. **squamosum** n. var. Apparently a hybrid between *S. alni* and *S. castaneum*.

Plates 2 and 25

Fungus body resupinate, the patches of growth being intermediate in size between *S. alni* and *S. castaneum*. Color about Saccardo's umber, sometimes brown with a distinct grayish tinge (No. 8485). Margin determinate or indeterminate. Surface flaky, due to the incompletely formed top layer. The flakes, which form all the top layer present in this species, vary from about 1 up to several square mm., crowded and anastomosing or scattered with 1 or 2 mm. between each flake. In section the entire plant is exceedingly thin, the flakes papery thin. Pillars scarce, the flakes usually arising directly from the basal layer. Pillars when present short and thick. Probasidia formed over the surface of the flakes and also over the basal layer except beneath the flakes; spherical, 9–11.3 $\mu$  thick; basidia 4–5 x 40–50 $\mu$ , cylindrical, 4-celled (No. 8323). Spores as in *S. alni* except slightly smaller. Associated with scale insects, some of which are parasitized by irregular coils.

This hybrid form can easily be recognized by its brownish color, exceedingly thin structure, and the flaky nature of the upper layer. It occurs with *S. alni* and *S. castaneum* and is possibly a hybrid formed by the crossing of these two species. The forms belonging here were first segregated under *S. alni*.

Specimens examined:

South Carolina: Near Myrtle Beach, on *Liquidambar styraciflua*, common, August 29, 1931, 9087, 9088, 9089; St. Helena's Island, on *Liquidambar styraciflua*, March 21, 1930, J. N. Couch, coll., 8479; Springwood, on *Liquidambar styraciflua*, with *Aspidiotus (Cryptophyllaspis) liquidambaris* Kot., July 3, 1928, J. N. Couch, coll., 8325; also on *Hicoria* with *S. alni*, 8324.

**Septobasidium lepidosaphis** n. sp.

Plates 6 and 19

Fungus body resupinate, extending over the surface of the stem and leaves of *Citrus* sp., covering a relatively small area (6 sq. cm.) in my specimens. Carob or Van Dyke brown (Ridgway). Surface characteristically covered with numerous, erect, pointed spines, which may be 1.2 mm. high; spines usually anastomosing considerably; surface sometimes with a wavy or irregular honeycomb appearance. Margin usually indeterminate but sometimes distinct. In section composed

of two or three regions: (1) the subiculum which is very thin,  $10\text{--}20\mu$  thick, threads of subiculum  $3\text{--}6.3\mu$  thick, septate without clamp-connections but with much anastomosing between threads; (2) from the subiculum arise a tangled weft of hyphae or more frequently hyphae which unite to form thin pillars which in turn unite to form larger upright spines, spines up to  $75\mu$  thick, usually thinner, hyphae of spines  $4.2\text{--}5\mu$  thick, septate without clamp connections, usually straight and rarely branching. (3) In some specimens a third region may extend over the tops of the spines, forming an irregular hymenial layer. Probasidia formed over the marginal region of the subiculum and over the top layer if a top layer is formed, and rarely on the spines, spherical  $8.4\text{--}12.6\mu$  thick, usually about  $9.5\mu$  thick, wall hyaline and rather thin (in my material). (Along with the probasidia are numerous enlarged bladder cells or perhaps aborted probasidial cells); probasidia germinating to form an elongated, straight cylindrical or sometimes curved, 4-celled basidium,  $4.2\text{--}6.3 \times 31.5\text{--}46\mu$ , usually about  $5.4 \times 35\mu$ ; sterigmata small, about  $4.2\mu$  long; spores strongly bent-elliptic,  $3.2\text{--}4.2 \times 10.9\text{--}13.8\mu$ .

Associated with the purple scale insect (*Lepidosaphes beckii*), some of which are parasitized by irregular coils while others are unharmed by the fungus. The fungus passes through the vaginal pore of the parasitized insects.

This species is very distinct from any other one so far described and may easily be recognized by the brownish color, dense tall spines, the sometimes coiled basidia, and most striking of all characters—the fact that the probasidia and basidia are formed on the flat thin margin as well as on the top layer when a top layer is present.

If infection of the young occurs here by the bud cells which come from the spores as in *S. Burtii*, the fact that the latter are borne on the margin would facilitate the infection of young migratory insects which happened to crawl out over the margin as the spores were being formed.

#### Specimens examined:

Florida: Okeechobee, on *Citrus grandis* with *Lepidosaphes beckii*, Jan. 20, 1933, L. S. Light, coll., in Univ. of Florida Herb., 8933 and U. N. C. Herb., 9345; near Venus, on *Citrus aurantifolia*, March 23, 1933, R. B. Linger, coll., in Univ. of Fla. Herb., 9053, and U. N. C. Herb., 9363.

Brazil: Viçosa, Estado de Minas Gerais, on *Citrus* sp., June 10, 1929, A. S. Müller, coll., type, in Müller Herb., 43 (see *Phytopathology* 23: 734-737. 1933) and U. N. C. Herb., 9721; Lagoa Grande, on native tree, June 24, 1934, A. S. Müller, coll., in Müller Herb., 831, and

U. N. C. Herb., 9961; also near Viçosa, on *Vernonia crotonoides*, July 10, 1934, A. S. Müller, 832, and U. N. C., 9962; also on *Mangifera indica*, A. S. Müller, 833, and U. N. C., 9963. Müller's collections also deposited in Cornell Univ. Herb.

**Septobasidium Curtisii** (B. and D.) Boedijn and Steinmann. Bull. Jardin Bot. Buit. 11 (3): 181. 1931.

*Glenospora Curtisii* Berkeley and Desmazières. Journ. R. Hort. Soc. 4: 243. 1849.

### Plate 5

Fungus resupinate, thin, growing in effused patches which often cover an area equal to 30 or 40 square centimeters. Surface nearly smooth in some specimens but more often dotted with minute areolations, considerably cracked in old specimens (in some specimens, especially those on oak, the surface is roughened by upright pillars of hyphae); usually black with a purplish tint (about plumbeous black of Ridgway) but often fuscous. Margin variable, sometimes thick, terminating abruptly and then concolorous with the main surface, usually thin during the growing season and of a lighter color than the main surface, whitish with a purplish sheen toward the outer edge, and sometimes indeterminate. Marginal region dotted with numerous patches of elevated hyphae which sometimes are star-shaped, umbrella-shaped, tent-shaped or shaped like an Eskimo hut. In section about 200–400 $\mu$  thick, sometimes compact throughout but more often composed of three more or less distinct regions: (1) the subiculum which grows horizontally over the bark, very thin, hyphae of subiculum 4–5 $\mu$  thick in marginal region with much anastomosing between threads; (2) the middle region which arises from the subiculum sometimes as short thick pillars, the threads of which quickly branch out to form the top layer; (3) top layer 60–300 $\mu$  thick, the thickness depending upon the age, threads of top layer and pillars about 4 $\mu$  thick; in young specimens composed of only one hymenial region while in old specimens the top layer may be stratified by the successive formation of several hymenial layers. Hymenium composed of probasidia and basidia. Probasidia formed during the fall and early winter (young, small, thin-walled Oct. 10, mature Dec. 10), germinating into the basidia during the spring and early summer; mature probasidia 10.8–16.8 $\mu$  thick (most about 12 $\mu$  thick), spherical, wall about 1.5 $\mu$  thick, often with numerous minute furrows on the inner side which give the wall, in a section view, the appearance of being pitted; basidia 6.3–7.6 $\mu$  thick by 62–70 $\mu$  long, counting the stalk, straight, thickest in the middle, often breaking off from the probasidium and its stalk; stalk 10–20 $\mu$  long; basidium becoming divided by three transverse walls into four cells, each cell sprouting a short pyramidal shaped sterigma, which is very peculiar in that, after the formation of the basidiospore, the sterigma remains full of protoplasm and then buds several

very minute sporidia; basidiospores hyaline, usually bent-elliptic, becoming once or thrice septate,  $3-4.2 \times 13-21\mu$ , up to  $29.4\mu$  long. Conidia formed over the lower surface of the fungus, globose, borne in chains.

Associated with *Chionaspis sylvatica* Sanders, *C. gleditsiae* Sanders, *Chrysomphalus obscurus* Comst., and *Aspidiotus* sp. on a large variety of trees and shrubs, being perhaps the most widely distributed and commonest species in the United States, also reported from Java on tea by Boedijn and Steinmann.

The present species because of similar habitat and color may be confused with *S. Patouillardii* Burt. Burt's material of *S. Patouillardii* was collected on living branches of *Fraxinus*, *Liquidambar*, and *Nyssa*, which hosts I have found to be very common ones for the present species. Burt (1916) describes his plants as being "aniline-black at first, becoming fuscous in the herbarium," colors which agree with the present species. The two plants may be separated by gross and microscopic characters. *Septobasidium Patouillardii* Burt always shows a distinct differentiation into three layers, the top layer being supported by pillars. In the present species the layered condition is often quite indistinct and the plant is never distinctly three-layered throughout. In probasidial and basidial characters the two plants are quite distinct. In *S. Patouillardii* Burt the probasidia are small and elongated in shape; in the present species they are large, distinct, thick-walled, and globose. In the former the probasidial cell elongates to form a two-celled basidium, the probasidial cell therefore does not persist after the formation of the basidium; while in the present species the four-celled basidium sprouts from the probasidial cell, the latter persisting for a long time as an empty cell after the basidium has matured.

The fungus-insect combination causes considerable damage to certain trees and shrubs, particularly species of *Fraxinus* and *Nyssa*. The commonest type of injury shows itself as a cracking of the bark with a marked hypertrophy of the underlying tissue and sometimes the injury may show itself in the form of witches' brooms.

#### Specimens examined:

New Jersey: Newfield, on *Nyssa multiflora*, winter 1874, J. B. Ellis, coll., probasidia abundant,  $10-14\mu$  thick, many  $12.6\mu$ , no basidia. Associated with *Chionaspis* sp., many of which are not parasitized and are giving birth to young. Typical (In U. S. D. A. Herb., De Thümen, *Mycotheca Universalis*, 292).

Maryland: Hyattsville, on *Nyssa*, F. L. Scribner, coll. Typical.

Virginia: Clarendon, on living limbs of *Nyssa sylvatica*, April 16, 1923, J. R. Weir and W. W. Diehl, colls. Two other collections from Va.; also near Roanoke, April 21, 1931, C. L. Shear, coll; (all in U. S. D. A. Herb.)

North Carolina: Exceedingly common from mountains to coast, represented by 60 collections, the only species common in mountains, J. N. Couch, coll; also collected by W. W. Diehl, on *Nyssa*, by F. L. Stevens on *Juglans*, and by P. O. Schallert (U. S. D. A. Herb.).

South Carolina: Common, represented by 14 collections.

Georgia: Near Vaughan, on *Ilex decidua*, Nov. 3, 1933, B. B. Higgins, fertile, 9336; near Valdosta on *Nyssa*, 9300; near Darien, Ravenel, coll., 333, probasidia very abundant,  $10.5\text{--}13\mu$  thick, often slightly rough, no basidia seen, typical; also on *Carpinus*, (U. S. D. A. Herb.); near Cairo, on *Pyrus communis*, Ogara and Worth, colls., Feb. 2, 1903 (U. S. D. A. Herb.); near Fort Valley, on *Viburnum*, Jan. 19, 1922; also March 18, 1922, J. C. Dunegan, coll. (in L. O. Overholts Herb., 8114, also in U. S. D. A. Herb.).

Florida: Common as far south as Sebring. Near Gainesville, on *Fraxinus*, October 4, 1933, G. F. Weber, coll. (Univ. Fla. Herb., 9412. Several collections, on *Nyssa*, J. N. Couch; also on deciduous tree, Calkins, coll., winter of 1886 (U. S. D. A. Herb.).

Mississippi: Pascagoula, very common on *Nyssa*, and *Fraxinus*, J. N. Couch.

Alabama: Near Auburn, on *Nyssa*, F. S. Earle and C. F. Baker, colls., 2240, Jan. 16, 1897, typical; also on *Nyssa sylvatica*, Dec. 5, 1922, L. E. Miles, coll. (both in U. S. D. A. Herb.).

Louisiana: On *Magnolia* sp., Langlois, coll., Nov. 4, 1888, many empty probasidia, no basidia; near Pointe a la Hache, on *Carpinus*, April 20, 1888, Langlois, coll., many probasidia, no basidia; on *Gleditsia triacanthos*, Jan. 5 and 6, 1886, Langlois, coll., material abundant, probasidia  $10\text{--}13\mu$ , some minutely spiny, no basidia seen (Langlois, 179); near Monroe, on *Nyssa sylvatica*, Jan. 30, 1928, E. L. Dennison, coll. (all in U. S. D. A. Herb.); also near Opalousas, on *Carpinus* (?), April 16, 1932, C. L. Shear, coll., fertile, the best fruiting material I have yet seen of this species, probasidia  $12\text{--}16.8\mu$  thick, spores up to  $30\mu$  long (in U. S. D. A. Herb.); near Madisonville, on *Nyssa*, Nov. 6, 1932, C. A. Brown, 553, also in U. N. C. Herb., 9953; near New Orleans, very common on *Nyssa* and *Fraxinus*, Dec. 31, 1931, J. N. Couch, coll.

Arkansas: Near Little Rock, on *Gleditsia triacanthos*, 9374, and *Quercus phellos*, 9375, April 12, 1933, D. V. Baxter, coll. The collection on *Gleditsia* is not typical, having a much better developed top layer than usual.

Guatemala: On angiosperm tree, Dec. 28, 1906, W. A. Kellerman, coll., pillars very abundant, about one millimeter tall, hymenium forming a smooth surface over tops of pillars and hence not typical, probasidia very abundant, spherical, 8.4-12.6 $\mu$ , most about 9 $\mu$  thick, color and wall characters as in Chapel Hill and Ravenel plants, basidia not seen. Before positive determination can be made, basidia should be studied (in U. S. D. A. Herb.).

Guadalupe: Near San José, on *Erythrina*, May 1915, Condert, coll., in Patouillard Herb. Harvard Univ., with *S. Leprieurii* (Mont.) Pat. This material is much like the above collection from Guatemala.

Java: Marywattie Estate, on *Thea*, July 1930, Steinmann, coll. (Herb. Hort. Bot. Bog., 11821, also in U. N. C. Herbarium), probasidia present, no basidia, many upright spines, no smooth hymenial surface.

### Septobasidium Cokeri n. sp.

#### Plates 17 and 39

Fungus body resupinate, covering an area of several square centimeters (up to 15 cm. in diameter) on the bark of a variety of trees and shrubs. Typically pure white throughout when fresh and frequently retaining the pure whiteness in the herbarium, sometimes creamy on the surface and becoming brown upon aging, sometimes becoming blackish in the older parts. Margin determinate. Surface smooth and usually free from cracks except in old specimens. In section 0.6-1.3 mm. thick, composed of three distinct layers, frequently stratose: (1) the subiculum which extends over the bark 40-70 $\mu$  thick, threads of subiculum 3-3.7 $\mu$  thick; (2) the pillars, which arise from the subiculum, arising singly or sometimes in tufts, each pillar with a circlet of short threads at its base, these threads encrusted with crystals; 18-185 x 370-510 $\mu$ , composed of much septate threads sometimes constricted at the septa and frequently thick-walled, 4-5.5 $\mu$  thick. The pillars often arise in concentric rows on the margin, each row being about 0.25 mm. apart. In the older parts this concentric arrangement of the pillars is not evident. Threads of pillars branching above to form (3) the top layer over which the hymenium is formed, 70-148 $\mu$  thick; threads 4-5.9 $\mu$  thick, frequently thick-walled, with a very small lumen and sometimes constricted at septa. Hymenium 25-50 $\mu$  thick, composed of probasidia and hyaline paraphyses. Probasidia globose, subglobose, or more usually pyriform, 10 x 11-16 $\mu$ , sometimes subtended by one or more

large cells, probasidial wall often considerably thickened, up to about  $2\mu$  thick. Threads in hymenium  $2\text{--}3\mu$  thick, recurved but not wavy and of more or less even diameter throughout. Basidia long-cylindrical or sometimes curved,  $4.4\text{--}6.2 \times 40\text{--}55\mu$ , 4-celled and with a long stalk which remains attached to the empty probasidial cell; sterigmata lateral, small, about  $5\mu$  long. Spores  $3\text{--}3.7 \times 14.8\text{--}22.4\mu$ , bent-elliptic.

Associated with scale insects some of which are parasitized by irregular coils, while others are unharmed by the fungus. Most commonly found on *Quercus* spp., also on several other trees and shrubs. Distributed from New Jersey southwards to Florida. Frequently found with typical *S. pseudopedicellatum*, *S. Mariani*, *S. Burtii*, *S. Curtisi*, and *S. apiculatum*.

This species has been included in *S. pseudopedicellatum* by Burt (1916) and Coker (1920) but may be distinguished as a rule by its almost snow white or creamy color throughout. This whiteness is very distinctive and by marking certain specimens and keeping them under observation through the seasons it has been found that the whiteness is not a mere seasonal condition but persists throughout the year. The very distinct unbranched pillars, which in the marginal region arise frequently in concentric rows, the pillars in each row often being so close to each other as to form a solid phalanx, are also characteristic. Even in older specimens the older surfaces of which are buffy or brownish in color the pillars will always be whitish or light buff and never dark brown as in *S. pseudopedicellatum* Burt. Another distinguishing character of this fungus is in the hyphae. The subhymenial hyphae are frequently thick-walled, constricted at the septa and with small lumina. Such hyphae resemble those of *S. apiculatum* n. sp. with which this form sometimes occurs. The basidia and spores are also smaller than those in *S. pseudopedicellatum*.

#### Specimens examined:

New Jersey: Newfield, on living saplings of *Quercus tinctoria*, Jan. 1900, J. B. Ellis Herb., also in Farlow Herbarium. Burt included this under *S. pseudopedicellatum* but wrote on label: "This does not have exactly the structure of *S. pseudopedicellatum*. Perhaps it is weathering that has caused change."

Virginia: Mecklenburg Co., on *Cornus florida* with *S. filiforme*, July 13, 1927, J. N. Couch, coll., 8179.

North Carolina: Chapel Hill, on *Quercus rubra*, 8439, 8440, 8441, 9108, 9326, 9385, 10004, type; on *Quercus velutina*, 10000; on *Quercus*

*palustris*, 8303A, 8563; on *Quercus phellos*, 8391, 9224; on *Quercus montana*, 9102; on *Cornus florida*, 8394, fertile; also on *Cornus amomum*; on *Fagus grandifolia*, 8187; on *Acer negundo*, 9072, 9109; Cary, on *Quercus phellos*, John R. Raper, coll., 9430; Pasquotank Co., on *Hicoria aquatica*, April 4, 1933, Willard Hewitt, coll., fertile, 9367; near Magnolia, on *Quercus*, Jan. 1931, A. C. Mathews, coll., 9966. Beautiful specimens.

Florida: Near McClenney, on *Quercus* sp., Jan. 18, 1933, W. L. Kersey, coll., Univ. Fla. Herb., 8923, also U. N. C. Herb., 9344.

**Septobasidium leprosum n. sp.**

Plates 12 and 29

Fungus body resupinate, forming rather small irregular patches on the bark of the younger limbs of living trees; usually not more than two or three centimeters in diameter, rarely as much as four or five; white. Surface irregular in young specimens, the marginal region dotted with numerous, small (about 1 mm. in diameter) apparently isolated patches of growth, marked in the older regions by numerous sinuous, anastomosing channels; as growth proceeds these channels are more or less closed so that numerous unconnected round or irregular pin holes are left in the surface; in the still older regions of growth the pin holes are closed. On *Ilex* and *Hicoria* the top layer never becomes a smooth continuous surface but remains in the form of small patches 1 or 2 mm. wide (hence the name *leprosum*). Margin indeterminate. In section exceedingly thin,  $60\text{--}130\mu$  thick, rather indistinctly differentiated into layers or regions except where there are chambers or tunnels. In such regions composed of a very thin subiculum about  $12\text{--}20\mu$  thick, from which arise a few thick (usually about  $65\mu$ ), short (about  $45\mu$  tall) pillars which partly support the top layer, the roof of the chambers or tunnels; top layer  $40\text{--}50\mu$  thick. Threads septate, without clamp connections, hyaline; about  $4.2\mu$  thick in subiculum, with thickened walls, threads thinner in hymenial region,  $2.1\text{--}2.5\mu$  thick, with thin walls. Hymenium formed over the entire surface, composed of probasidia and basidia and simple, slender threads. Probasidia globose or slightly pyriform,  $10\text{--}11 \times 10\text{--}13.8\mu$ , hyaline, with slightly thickened wall; formed during the early winter and germinating in the early spring to form a long, cylindrical, four-celled basidium. Probasidium becoming entirely empty during germination and persisting as an empty sac. Basidium  $6\text{--}6.5 \times 50\text{--}56\mu$ , straight, sprouting a short sterigma from each of the four cells and normally bearing four spores. Spores white, smooth, bent-elliptic,  $4.2\text{--}5 \times 12.6\text{--}15\mu$ .

Symbiotically associated with scale insects, some of which are parasitized by irregular, gnarled coils of hyphae and others of which are not parasitized.

This species can be easily recognized by its white color, very thin structure, by the irregular holes in the plant body, and by the numerous, small, apparently isolated, patches of growth around the margin.

This plant shows a remarkable adaptation to a symbiotic relation with scale insects. In the plant body there are numerous chambers connected by tunnels which open to the exterior through the irregular holes described above. The floor of these chambers and tunnels is formed by the thin subiculum and the roof is formed of a thin but compact mat of threads which bear the hymenium. The roof of each chamber is supported by one or two thick short pillars. This adaptation can be better seen if the development of the fungus is followed. If a young specimen or the margin of an old specimen is examined one sees numerous, small, apparently isolated, patches of growth. If these patches are examined under a dissecting microscope, they are seen to resemble the snow huts of Esquimaux in shape. These little huts arise by upgrowths of hyphae from the subiculum. As growth proceeds the tips of the hyphae bend over toward each other, finally coming in contact and forming an arch. These little huts are about a millimeter apart. As development goes on, the roofs of the huts branch out and grow toward each other until the space between the huts is closed, except for numerous tunnels which connect the huts with each other, and connect the older huts with the newer ones, and thence with the exterior.

These huts are the homes of the scale insects. The houses containing parasitized insects finally become completely closed while the houses of the healthy insects remain open, communicating with the exterior through the tunnels. As the young hatch out they crawl out to the new houses and settle down there.

This species is commoner than my collection data indicate. It is so inconspicuous as to be easily passed over.

#### Specimens examined:

Virginia: Mecklenburg Co., on *Cornus florida* with *S. filiforme*, 9179.  
North Carolina: Chapel Hill, on *Ilex decidua*, several collections from same tree, 9150, 9352, 9372, type; on *Cornus amomum*, Jan. 20, 1928, J. N. Couch, coll., 8302A; on *Fraxinus* sp., March 8, 1929, P. A. Rhodes, coll., 8387; on *Crataegus* sp., Dec. 20, 1931, J. N. Couch, coll., 9149.

South Carolina: Near Charleston, on *Cornus florida*, March 19, 1930, J. N. Couch, coll., 8463; Springwood, on *Hicoria*, July 2, 1928, J. N. Couch, coll., 8324a.

Louisiana: Near Baton Rouge, on *Ilex decidua*, Dec. 31, 1931, J. N. Couch, coll., 9171.

**Septobasidium fumigatum** Burt. Ann. Mo. Bot. Gard. 3: 332. 1916.

Plates 4 and 23

Fungus body resupinate, covering extensive areas on the trunks and limbs of trees, sometimes extending from the base nearly to the top of a tree; mummy brown or snuff brown, or sepia (on maple) to nearly black (on *Cornus*) where the hymenium has not been formed. Hymenium light to dark gray (pallid mouse gray or light mouse gray to mouse gray of Ridgway), contrasting strikingly with the brown where the hymenium has not formed. Hymenial surface smooth except for a few cracks, sometimes with numerous holes 0.3–0.5 mm. in diameter; surface without hymenium characteristically spongy or alveolate. Margin determinate or indeterminate, sometimes with fine rhizomorphs. In section 600–1400 $\mu$  thick, usually about 1 mm. thick, composed of loosely interwoven, branched, septate, non-nodose hyphae, 3.8–4 $\mu$  thick, which arise from the substratum to hymenial region, not differentiated into pillars. Hymenium 33–50 $\mu$  thick, composed of once or twice coiled, thin-walled, hyaline threads about 3 $\mu$  thick, and probasidia and basidia. Probasidia spherical to subspherical, with a hyaline wall when young, brownish and punctate when mature, 12–16 $\mu$  in the greatest dimension, sprouting and emptying their entire contents to form club-shaped basidia. Basidia distinctly thicker at the distal end, four-celled when mature, 7.5–9.2 x 40–56 $\mu$ , each cell giving rise to a sterigma (about 8–10 $\mu$  long) on the end of which is borne a spore; spores bent-elliptic, 4.6–8 X 15–21 $\mu$ , most 6.3 x 16 $\mu$  (no. 8458).

Distinguished by the mouse or pale mouse gray color of the hymenium and the sepia, mummy, or snuff brown of the vegetative part, the lack of pillars, the spongy structure of vegetative part, the coiled threads in the hymenium, and basidia which are distinctly enlarged in the distal part. Related to *S. alveolatum* in vegetative structure but may be separated from that species by the smaller reproductive structures and the straight basidium in *S. fumigatum*.

Associated with *A. tenebricosus* and *Aspidiotus* sp., some of which are parasitized by spindle-shaped hyphae connected by fine threads. These hyphae are of two sorts: the main threads composed of long cells from which arise coiled or twisted hyphae composed of shorter cells. Vast numbers of the insects of both species are free from parasitism, carrying on their life histories year after year beneath the thick spongy mass of fungal tissue.

This is one of the commonest species from South Carolina southward

into Florida, being most frequently found on *Acer rubrum*. In Highlands Hammock near Sebring, Fla., it was by far the commonest species, occurring with the scale insects on practically every red maple tree in the hammock. I found one tree of *Acer rubrum* with a trunk three feet in diameter the main trunk of which was heavily infected. Frequently the stems of smaller trees may be almost completely clothed by the fungus for several feet. Such heavily infected trees were always unhealthy, showing large numbers of dead limbs in infected areas. Also occurs on mulberry, *Cornus*, and *Tilia*. Extending northward as far as South Carolina and westward as far as Louisiana.

I have studied type material (Mo. Bot. Garden Herb., 43822) collected on the trunk of living *Acer rubrum*, Santee River, near Gourdin, South Carolina, and find that my material agrees with the type. It should be pointed out, however, that in Burt's drawings of the type, figure 12, he fails to show the probasidial cell at the base of the basidium. Such drawings along with Burt's statement in the text convey the impression that the basidium is formed by the elongation of the probasidial cell and that the latter does not persist after the formation of the basidium. An examination of the type material shows that the probasidial cell becomes empty during the formation of the basidium, the contents of the former passing into the latter. The probasidium usually persists as an empty cell at the base of the basidium though sometimes it may collapse, but even then can be made out.

#### Specimens examined:

South Carolina: Type, Gourdin, on *Acer rubrum*, Nov. 4, 1914, C. J. Humphrey, coll., in Mo. Bot. Gard. Herb., 43822, Humphrey Herb., 2588, and Farlow Herb.; near Charleston, on *Acer rubrum*, abundant, March 19, 1930, J. N. Couch, coll., 8458, fertile; near Myrtle Beach, on *Acer floridanum*, August 29, 1931, J. N. Couch, coll., 9098; near Jacksonboro, on *Acer rubrum*, J. N. Couch, coll., 8476.

Georgia: Near Valdosta, on *Acer* sp?, March 17, 1932, J. N. Couch, 9297 and 9301.

Florida: Near Brooksville, on *Tilia* sp., Feb. 1922, J. A. Stevenson, 1641, in U. S. D. A. Herb., det. by E. A. Burt; also on *Acer*, J. A. Stevenson, 1673, in U. S. D. A. Herb., det. by J. R. Wier; near Sebring, Highlands Hammock, on *Acer rubrum*, March 14, 1932, J. N. Couch, coll., 9261, 9255, 9260, 9269, fertile; also on mulberry-like plant with white latex, 9275; also on *Cornus ammonum* and *C. florida*, 9267 and 9267a.

Louisiana: East Baton Rouge parish, on *Acer rubrum*, March 19, 1932, C. A. Brown, 339, and U. N. C. Herb., 9964; near New Orleans on *Cornus amomum*, Dec. 31, 1931, J. N. Couch, coll., 9158, fertile.

**Septobasidium cremeum** n. sp.

Plates 12 and 31

Fungus body resupinate, closely adherent to the bark, forming areas as much as 10 x 10 cm. Younger areas light buff, older regions cinnamon-brown. Surface at first smooth, becoming cracked into small irregular areas as the plant ages. Margin very irregular, usually indeterminate. In section up to  $225\mu$  thick, usually about  $210\mu$  thick in well developed specimens, composed of three layers except in the marginal region: (1) subiculum usually very thin, up to  $33\mu$  thick, composed of hyaline, septate, non-nodose, hyphae; (2) middle layer composed of very short pillars; (3) top layer  $60$ – $130\mu$  thick. Hymenium about  $35$ – $45\mu$  thick, hyaline in color and hence sharply distinct from the lower part of the top layer which is brownish, threads of hymenium  $2.2$ – $3.5\mu$  thick, colorless, densely packed, branched, coiled, and entangled. Threads of context and pillars  $3.8$ – $4.2\mu$  thick, septate without clamp-connections, brownish under microscope. On the margin the hymenium may sometimes be developed not only on the top layer but also over the subiculum. Probasidia subglobose, about  $8$ – $9\mu$  thick, the thread which bears the probasidium may be attached to it at the side or even top (i.e. the end toward the surface), as well as at the bottom; basidia usually coiled,  $4.2$ – $5$  x  $35$ – $40\mu$ , divided into four cells at maturity, each of which may give rise to a very long sterigma and bear a spore. Spores bent-elliptic,  $3.8$ – $5$  x  $11.5$ – $16.8\mu$ , not becoming septate on the slide.

Symbiotically associated with *Aspidiotus (Cryptophyllaspis) liquidambaris* Kot., some of which are parasitized by irregularly coiled hyphae, while others are not parasitized. The coiled hyphae, or haustoria, of the fungus connect with the main body of the fungus by means of hyphae which pass through the insect's derm by the mouth. These hyphae do not appear to interfere with the sucking operations of the insect, for the insect, though it may become heavily parasitized continues to live and suck the plant juice. The insects which are not parasitized reproduce young and carry on the life of the insects.

This species may be easily overlooked because of its inconspicuous color and thinness. It is related to *S. alni* and some of my specimens strikingly resemble that plant in color, in marginal characters, and in the pillars. The present species generally lacks the rich deep brown color of *S. alni*, being usually much lighter in color. It may also be

distinguished from *S. alni* by the coiled hyphae in the hymenium and the coiled basidia.

It is possible that the present species is a hybrid between *S. alni* and *S. tenue*.

Specimens examined:

Florida: Near Jacksonville, on *Liquidambar styraciflua*, with nearly black variety of *S. Burtii*, *S. sinuosum*, *S. castaneum*, *S. alni* and *S. tenue*, March 11, 1932, J. N. Couch, coll., type in U. N. C. Herb., 9232; La Cross, on *Ilex glabra* with *Aspidiotus juglans-regiae*, May 1, 1933, Geo. F. Weber, coll., in Univ. Fla. Herb., 9188, and U. N. C. Herb., 9395.

*Septobasidium Sydowii* n. sp.

Plates 5 and 30

Fungus body resupinate, forming circular patches up to 5 cm. in width. Chestnut brown or darker in the older regions, light grayish brown in the younger or fruiting regions. Surface smooth near the margin over a zone about 6-8 mm. wide, the rest of the surface conspicuously cut up by many deep fissures which are up to 1 mm. wide. Margin sharply determinate, with a minutely scalloped appearance caused by minute holes which lead back into short tunnels in the tissue of the fungus. In section about 1 mm. thick, very compact and hard, up to about 1.4 mm. thick, differentiated into context and hymenial regions. Context faintly stratose, composed of densely packed, entangled, rather sparingly branched threads which have mostly a vertical direction. Threads deep brown under microscope, thick-walled, rarely septate, without clamp-connections,  $3.6-5\mu$ , mostly  $4.2\mu$  thick. Hymenium  $90-115\mu$  thick, stratose, light colored and thus distinct in color from the context, threads vertical, thin-walled, collapsing easily, about  $2.8-3.5\mu$  thick; probasidia subglobose or ovoid,  $9-10.5 \times 13-15\mu$ , germinating to form a once coiled basidium, collapsing soon after basidia are formed. Basidia about  $6-7 \times 30-40\mu$ , 4-celled, sterigmata about  $6-10\mu$  long. Spores about  $3.8-4.3 \times 15.5-20\mu$ , bent-elliptic, sometimes somewhat S-shaped, becoming thrice septate.

Symbiotically associated with scale insects, some of which are parasitized by irregularly coiled haustoria while others are free from fungal infection.

The specimens from Texas are light grayish brown and the fissures run out to the margin. The margin also differs from that in the Philippine material in showing short pillars or tufts of threads. The surfaces

of the two plants are cracked in the same way and the microscopic characters of hymenium, probasidia, basidia and spores agree.

This species may readily be distinguished from all other species of *Septobasidium* which I have studied by the peculiar cracked surface. The fungus has the appearance suggesting a miniature bit of baked, finely cracked clay.

The fungus-insect relationship is obviously a very interesting one. Numerous healthy (i.e. uninjected by the fungus) adult insects were found partly buried in the cracks, the posterior part of the ventral and dorsal scales projecting up through the fissures, the scales reminding one of the bivalved shell of an oyster. These adults contained many young and, judging by the widely opened condition of the genital pore, were in the act of giving birth to young. In the tunnels near the margin many dried up, but non-parasitized young were found and farther back in the tunnels there were half grown insects. A considerable number of insects were infected, and such insects were always completely covered by the fungus.

This fungus was first recognized as a new species by Dr. Sydow and turned over to me for study. I take great pleasure in naming it in his honor.

#### Specimens examined:

Philippine Islands: Province of Sorsogon, on *Pterocarpus*, Elmer, coll., 14820. Type.

Texas: Near Austin, on *Ulmus crassifolia*, Sept. 7, 1934, J. J. Taubenthal, coll., U. S. D. A. Herb. and U. N. C. Herb., 9868.

#### *Septobasidium taxodii* n. sp.

#### Plate 42

Fungus body exceedingly thin, forming resupinate crusts on the bark of young twigs of *Taxodium*. Dirty Mars brown in color. Margin indeterminate. Surface usually roughened by cracks in the bark, or sponge-like under a lens where the fungus overgrows insects. In section about  $100\text{--}250\mu$  thick, not divided into strata and without a distinct subiculum. Hyphae penetrating into and in between the dead cells of the outer bark. External threads densely entangled,  $2.1\text{--}4.2\mu$  thick, brownish, septate without clamp connections, branched, frequently recurved in the distal part. Probasidia  $10\text{--}12.6\mu$  thick, spherical, giving rise to a coiled (often helically) 4-celled basidium,  $5\text{--}6.3 \times 33\text{--}40\mu$  (the coil about  $16\mu$  across). Probasidium remaining as an empty cell after the basidium has been formed. Sterigmata  $5\text{--}6\mu$  long on the distal cells. Spores not certainly seen.

Associated with *Aspidiotus forbesi* Johnson on *Taxodium distichum*. Many of the insects are parasitized by irregular coils, the fungus passing through the insect's body wall at the vagina and anus. Occurring with *S. pseudopedicellatum* Burt and *S. Mariani* Bres.

Easily overlooked because of its thinness and inconspicuous brownish color. Its thin structure, brownish color, and coiled basidia distinguish it from most other species of *Septobasidium*.

Specimens examined:

Louisiana: Opelousas, on *Taxodium distichum*, April 16, 1932, P. R. Miller, coll., type in U. S. D. A. Herb. and U. N. C. Herb., 9938.

**Septobasidium filiforme n. sp.**

Plates 16 and 32

Fungus body perennial, resupinate, effused, occurring in patches of varying size up to 20 cm. long by 5 cm. wide. Color very variable, the young margin white, which is quite striking and conspicuous when fresh or damp; older regions pale buff in comparatively young specimens, becoming wood brown to deep buffy brown or army brown or natal brown, sometimes with a dusky purple tint; color fading considerably upon drying, surface usually becoming cracked after maturity into irregular patches about 1 cm. wide; the cracked edges often curling back somewhat and exposing the whitish subiculum; surface, except for cracks, very smooth. Whitish marginal region about 1-8 mm. wide, composed of young, undeveloped hymenium from beneath which a narrow border of the subiculum grows. Margin of subiculum often speckled with minute white dots,—the young pillars. In section 350-500 $\mu$  thick in young specimens, up to 800 to 1000 $\mu$  thick in old specimens, usually composed of three layers; in old specimens composed of a number of layers due to the annual formation of new pillars and an hymenium directly on top of the hymenium of the previous year: (1) the subiculum, which runs over the surface of the bark, white, 20-50 $\mu$  thick; threads of subiculum hyaline under microscope, thin-walled, 2-3.2 $\mu$  thick, septate without clamp connections; (2) the region of more or less vertical hyphae which arise from the subiculum and may adhere together to form the supporting pillars for the hymenium or may pass into the hymenium without forming the pillars; threads of this middle region 3.2-4.4 $\mu$  thick, branched when not forming pillars, but threads of pillars sparingly branched, thick-walled and rarely septate; pillars very variable in diameter, composed of compactly arranged threads for only about one-third the distance between their base and hymenium, distance between subiculum and top layer quite variable (150-400 $\mu$ ); (3) hymenium thin, 42-60 $\mu$ , rarely up to 90 $\mu$  thick, composed of probasidia and basidia in various stages of development and hyaline, slightly bent

threads about  $3\mu$  thick and numerous conspicuous narrow threads, with deep brown contents, which usually break up into pieces of irregular length; probasidia pyriform, borne laterally,  $7.7-11.8 \times 14-23\mu$ , sprouting a long narrow twisted and often coiled basidium  $4-5 \times 28-40\mu$ . Basidium usually 4-celled, of which only the first three cells form spores; not rarely 3-celled or only 2-celled. Sterigmata very long,  $20-30\mu$ , partially or completely collapsing after the spores are formed. Spores hyaline, bent-elliptic, narrowed at the mucro end,  $3.4-4 \times 13-21\mu$ .

Symbiotically associated with scale insects, some of which are parasitized by irregular coils, while others are left unharmed. The scale insects are parasitized through the anus and sometimes through both the anus and the genital opening. Through these openings a bundle of brown, thick-walled threads pass and within the insect these branch out into hyaline, thin-walled threads from which arise enormous clusters of the coiled haustorial threads.

Abundant on a large variety of trees and shrubs, but easily overlooked because of its comparatively small size. This species has been labelled in our earlier collections as *S. pseudopedicellatum* but can easily be separated from that form. Distinguished by the wide whitish margin contrasting with the much darker brownish color of the older regions; by its whitish subiculum, exposed in old specimens by the cracking of the upper layers. In microscopic structure it may be distinguished by the pyriform probasidial cells, by the peculiarly twisted or coiled basidia and *above all by the narrow threads with deep brown contents which break up into rods that adhere end to end*.

#### Specimens examined:

Virginia: Mecklenburg Co., on *Cornus florida* and *Liquidambar styraciflua*, July 13, 1927, J. N. Couch, coll., 9179, type, with *S. apiculatum* n. sp. and *S. Mariani*.

North Carolina: Chapel Hill, on *Alnus rugosa*, Jan. 24, 1920, J. N. Couch, coll., 4015, with *S. pseudopedicellatum*; on *Ligustrum chinensis*, Jan. 9, 1920, J. N. Couch, coll., 3923; on *Cercis canadensis*, Oct. 22, 1927, J. N. Couch, coll., 8273, very common; on *Ceanothus americanus*, also on *Hicoria* sp., October 20, 1927, J. N. Couch and W. L. Hunt, colls., 8263; on *Pyrus japonica*, 8446, 9077; on *Crataegus Marshallii*, 8290; on *Syringa vulgaris*, 9106; on *Acer Negundo*, 9105; on *Carpinus caroliniana*, with *S. Mariani*, and *S. apiculatum* n. sp., 3924, also 8190, 8237, 8291; on *Cornus amomum*, 8388, 8558, 9104; on *Cornus florida*, 8272, 8349, 9107, 9432; near Raleigh, on *Cornus florida*, May 15, 1929, B. B. Fulton, coll., 8409.

**Septobasidium** sp. Hybrid form between typical *S. pseudopedicellatum* and *S. Schweinitzii*.

Plates 13 and 35

I have found several cases of hybridization between *S. Schweinitzii* and *S. pseudopedicellatum*. In collection No. 8319 on ash from Lynch's River bottom, S. C., we found an American ash tree mottled with *Septobasidium* from the base to the ends of the branches. Typical *S. pseudopedicellatum*, *S. Schweinitzii*, *S. Patouillardii*, and *S. leprosum* were present, the first three being the more abundant. The *S. pseudopedicellatum* and *S. Schweinitzii* were hybridizing. The typical *S. pseudopedicellatum* had a buffy to dark brownish surface, a whitish subiculum and long, distinct, individual pillars on the margin and between the upper and lower layers. The *S. Schweinitzii* material was not exactly typical, being lighter colored and with the sterile upright threads in the hymenium more wavy than typical. The margin of the subiculum showed the typical tent-like structures rather than upright pillars. The *S. pseudopedicellatum* was about twice as thick as the *S. Schweinitzii* and hence even ignoring the color and marginal characters it was possible easily to distinguish the two species. In a number of places on the bark the two species were growing in contact along their contiguous margins but in such pieces one could easily tell where one species ended and the other began although the margins were apparently in intimate contact. In such specimens the vegetative and reproductive structures were apparently unaffected.

In a large number of cases the two species were growing together, forming a new type of growth which combined the characters of both. Such organisms were distinct enough from both parents in vegetative and reproductive characters to justify their being described as a new species. I am considering this, however, as a hybrid form between *S. pseudopedicellatum* and *S. Schweinitzii*.

The hybrid form varies from a few millimeters in diameter to several centimeters and is about as thick as typical *S. Schweinitzii*. Color a dirty washed out buff. Marginal subiculum pale purplish and with both pillars and upright hyphae, each group of which is arranged at first in a plate with the outline of an incomplete ellipse. The sides of the plate come together above forming a miniature tent, the open part of which is always directed toward the older part of the fungus, these tent-like structures being typical of *S. Schweinitzii*. The "tents" and pillars are not scattered irregularly but a row of "tents" alternates with rows of pillars. Hymenium hyaline, in some specimens composed of much

twisted upright threads and probasidia and basidia. In some specimens the hybrid hymenium may be formed over the old hymenium of *S. Schweinitzii*, the hybrid threads apparently coming through the old layer of *S. Schweinitzii*. Other specimens have been seen in which the hymenium may show a resemblance in vegetative characters to *S. pseudopedicellatum*. Still other types of variation in the vegetative structure of the hymenium occur in other specimens. Probasidia spherical or subspherical, 8.4–12.6 $\mu$ , averaging about 10 $\mu$  thick (12 measurements), collapsing after emptying. Basidium 4.2–5.8 x 32–41 $\mu$ , coiled, 4-celled, sterigmata about 3 $\mu$  thick by 12 $\mu$  long, usually straight, but sometimes coiled or twisted. Spores not seen.

I am unable to say whether these hybrids are formed by the grafting of the vegetative parts or by some kind of fusion of reproductive cells (bud cells from the spores). From studies on *S. retiforme* it seems very probable that hybrids are formed as follows: A scale insect hatches out beneath *S. pseudopedicellatum* or *S. Schweinitzii* and accidentally picks up the spores on its body and thus becomes infected. It now crawls away from the *S. pseudopedicellatum* out on the bark and finally settles down beneath a colony of *S. Schweinitzii*. The infecting cells of the fungus grow within the insect, as it develops, and eventually after the insect has moulted the last time the fungal threads of the *S. pseudopedicellatum* grow out through the anal or vaginal pore and anastomose with the threads of *S. Schweinitzii*, and thus the *S. pseudopedicellatum* is grafted onto the *S. Schweinitzii*. The course of events may proceed in exactly the opposite direction, i.e.: the insects may become infected with the spores of *S. Schweinitzii* and crawl away and settle down beneath *S. pseudopedicellatum*, etc.

**Septobasidium Schweinitzii** Burt. Ann. Mo. Bot. Gard. 3: 324. 1916.

Plates 11, 15 and 33

Fungus body perennial, resupinate, forming isolated or confluent patches growing over the surface of the bark, covering areas of a few to 15 or more sq. cm. Color quite variable, usually brownish with a purplish tint (benzo brown, or Van Dyke brown, or light cinnamon brown). Surface velvety, not glabrous, often minutely warted, sometimes considerably cracked in old specimens. Margin determinate, whitish, usually finely fimbriate (upper layer), margin of lower layer often more or less covered with v- or u-shaped plates of upright hyphae from which the pillars arise. In section 0.6–1 mm. thick, composed of three distinct regions: (1) the subiculum which extends over the surface of the bark and is whitish with a tint of purple in the young, fresh condition; usually extending only about 2 mm. beyond the margin of the upper layer; 60–

90 $\mu$  thick; from the basal layer numerous, short (60–70 $\mu$ ) upright, white, usually unbranched hyphae arise, bent at the upper end like a shepherd's crook; (2) the middle region composed of upright pillars which arise from the subiculum; pillars numerous, about 10–12 to a square mm., 20–65 $\mu$  thick, most 30–40 $\mu$  thick by 0.5–0.6 mm. high; (3) upper layer 125–270 $\mu$  thick, arising from the pillars and composed of much entangled, branched hyphae, hymenial region 60–100 $\mu$  thick, composed of upright branched threads between which there is considerable anastomosing, threads wavy and with slightly thickened walls toward the ends, about 3 $\mu$  thick. Basidia formed directly from the hyphal threads. Basidia 5 x 35–40 $\mu$ , coiled one to one and a half times, becoming divided by transverse walls into 5 cells, the basal cell being functionless. Basidia formed during the late fall and germinating during the spring and summer; each cell, except the basal one, germinating into a long tube which becomes swollen toward the distal end. The tubes are arranged more or less regularly side by side. From the distal end of each tube a long narrow (2 x 10–15 $\mu$ ) sterigma sprouts, which in turn bears a single spore on its end. Spores very irregular in size, 4.2–6.2 x 12.6–23.1 $\mu$ , bent-elliptic, white in print, rarely becoming once or thrice septate.

Common on ash, often occurring on the same limbs with *S. pseudopedicellatum* Burt. *S. Patouillardii* Burt and *S. Mariani* Bres., and not rarely confluent with these species. Symbiotically associated with scale insects (*Chionaspis gleditsiae* Sanders), some of which are parasitized by irregularly coiled hyphae, others remaining free from fungal infection.

This species may be recognized with the unaided eye by the striking color (benzo brown, etc.) and the peculiar marginal characters. Through the courtesy of Dr. Pennell, I have been able to study the type material of this species which is in the Schweinitz Herbarium at the Philadelphia Academy of Natural Science. The type material, consisting of a piece about half the size of one's smallest finger, was collected by Schweinitz near Winston-Salem, N. C., over one hundred years ago. Mr. K. B. Raper has collected this species for me near Welcome, N. C., only a few miles from Winston-Salem. The microscopic structure of the type material (Plate 33, figs. 4–8) is identically the same as that of my specimens. The color of the type has faded to a drab color, but the colored picture of the type as illustrated by Schweinitz in "Synopsis fungorum Carolinae Superioris," Tab. 2, fig. 3, agrees remarkably well with the color of my material. In my study of the type material, I have been unable to find the "erect probasidia" figured by Dr. Burt (Fig. 1a); nor did I find the "spore bearing organ" attached as shown in the same figure.

This species is fairly common around Chapel Hill and I have therefore been able to keep it under observation during the past two years and to work out some of the difficult points in its life history. No persistent probasidia are formed in this species, the basidium arising directly from the hyphal threads. This structure starts as a lateral tuberous cell which elongates and becomes coiled or irregularly twisted and finally becomes divided into five cells by transverse septa. Of these five cells the basal one is apparently functionless and may indicate the remains of a once normal probasidial cell, the other four cells are the "basidium." This structure formed during the early winter remains quiescent during the winter months. In the early spring each cell of the basidium sprouts a long tube which grows up to the surface of the hymenium. From the end of this tube a slender, long sterigma grows and on the end of this a spore is borne. During the formation of the spore the cell of the basidium, the long tube, and the sterigma become empty, the protoplasm, of course, passing into the spore.

This species is fairly abundant in certain localities, but does not seem to have a wide geographic range, being known with certainty only from North and South Carolina. It is represented by eleven collections in our herbarium. Usually occurring with *S. pseudopedicellatum* and *S. Patouillardii*.

#### Specimens examined:

North Carolina: Near Winston-Salem, Schweinitz, coll., in Schweinitz Herbarium, Philadelphia; same loc., on *Fraxinus*, with *S. Patouillardii* and *S. pseudopedicellatum*, Oct. 28, 1928, K. B. Raper, coll., 8370; same location Dec. 27, 1933, J. R. Raper, coll., 9341; near Chapel Hill, on *Fraxinus americana*, J. N. Couch, coll. Nos. 8373, 8374, 8379, 8397, 8398, 9989; near Wilmington, on *Fraxinus americana*, Dec. 28, 1921, J. N. Couch, coll., 5876.

South Carolina: Near McBee, on *Fraxinus americana*, June 30, 1929, A. B. Couch, coll., 8319. In this collection hybridization between *S. Schweinitzii* and *S. pseudopedicellatum* was taking place.

#### *Septobasidium Hesleri n. sp.*

#### Plates 13 and 18

Fungus body resupinate, rather inconspicuous, the patches of growth being small, up to about 10 cm. long by 2-3 cm. wide. Pallid, purplish gray in the regions of new growth, becoming a dull saayal or snuff brown in the older parts. Surface characteristically flaky due to the incom-

plete formation of the top layer; sometimes, however, the top layer may be complete. Margin determinate or indeterminate, dotted here and there with pillars or irregular "tents" or minute flakes. In section 250–400 $\mu$  thick, composed of three layers: (1) subiculum 12–20 $\mu$  thick, which is covered by upright, rarely branched, encrusted, hyaline threads, about 40 $\mu$  tall; (2) pillars 30–140 $\mu$  thick x 100–190 $\mu$  tall, usually rather few; (3) top layer 40–100 $\mu$  thick. Hyphae of subhymenial region 3–4.2 $\mu$  thick, dark-colored, branched; hymenial region 30–40 $\mu$  thick, composed of nearly hyaline, frequently dichotomously branched, coiled hyphae, 2.8–3.2 $\mu$  thick, between which there is much anastomosing, and basidia which are one to one and a half times coiled, about 4.5–5.8 x 32–38 $\mu$ , divided into four cells with an additional functionless basal cell. Basidial germination as in *S. Schweinitzii*. Each cell, except the basal one, gives rise to a long tube on the end of which a narrow sterigma is formed and on the end of which, in turn, a spore is formed. Spores 5–6.3 x 13–18 $\mu$ .

Symbiotically associated with scale insects (*Chionaspis gleditsiae*), some of which are parasitized by irregularly coiled haustoria, while others of the insects are free from parasitism and are in all stages of development.

The two collections of this species were in fruit but rather sparingly except on one piece of wood where the new species was growing in contact with a much more luxuriant growth of *S. pseudopedicellatum*. Along this line of contact in a zone about 0.3 cm. wide the new species was producing a vast abundance of basidia and spores. The *S. pseudopedicellatum* was not visibly affected by the contact. I have noticed other cases of greatly increased vigor in fruiting on the part of one species where two were in contact (e.g., *S. filiforme* and *S. Mariani*).

This species is closely related to *S. Schweinitzii* and *S. lilacinoalbum*, being perhaps a hybrid between the former and some unknown species.

The present species may be distinguished by its small size, thin, usually flaky structure, dull brownish color, and the inconspicuous "tents," "Esquimo huts," and pillars on the margin. The basidia and spores are as in *S. Schweinitzii* but in that species the hymenium is thicker and the sterile threads are wavy but upright while here the sterile threads are dichotomously branched and recurved, frequently coiled.

I am naming this species in honor of Dr. L. R. Hesler, who collected it.

#### Specimens examined:

Tennessee: Near Gatlinburg, on *Carpinus caroliniana*, June 20, 1931, U. N. C., 9906, and July 19, 1934, U. N. C., 9907, type, L. R. Hesler, coll.

**Septobasidium lilacinoalbum** n. sp. Hybrid between *S. Schweinitzii* and *S. Cokeri*.

Plates 16 and 34

Fungus body perennial, resupinate, occurring on the younger limbs; forming rather extensive confluent patches which often girdle the limbs and extend for a distance of 40 cm. The summer color of young fresh specimens is almost pure white but with a faint pallid-vinaceous tint, older regions ecru-drab, oldest regions dark, almost grayish black; the winter color is benzo brown or mummy or clove brown with a whitish mottled marginal region much as in typical *S. Schweinitzii*. Surface inherently smooth or sometimes minutely granulose with a lens in the young regions, often with circular elevations (the surface above each pillar being slightly elevated); in older regions becoming cracked into numerous irregular patches. Margin determinate, pure white in actively growing material. In section 360–430 $\mu$  thick, composed of three distinct layers: (1) subiculum rather thin, 60–80 $\mu$  thick, composed of a mat of brownish threads which extend over the bark and from which arise a weft of much thinner, hyaline, branched, curved threads which are partly encrusted with crystals, margin of subiculum extending about 1–2 mm. beyond margin of top layer; (2) middle layer composed of upright pillars which arise from the subiculum, pillars about 8–12 to a sq. mm.; very variable in thickness, 35–150 $\mu$  thick by 210–250 $\mu$  tall, single or in groups; hyphae of pillars 3–4.2 $\mu$  thick, septate, often slightly constricted at the septa, without clamp connections; (3) top layer arising from and supported by the pillars (the threads at the top of the pillar growing outward horizontally, each pillar forming a structure like an open umbrella; threads from the tops of adjacent pillars growing together finally forming a continuous top layer), at first very thin and composed only of horizontal hyphae; hymenium arising from and finally forming the larger part of the top layer, 60–100 $\mu$  thick, thin in the young regions, becoming thicker with age, composed of closely packed, more or less upright, much branched and twisted hyaline threads between which there is much anastomosing. Probasidia not formed. Basidia arising from the upright threads as small, elongated cells which directly grow into the coiled basidia. Basidium 4-celled with a fifth, basal, functionless cell; each cell of basidium giving rise to a long, thick sterigma on the end of which a spore is borne. Basidia coiled, 4.2–5 x 25–35 $\mu$ , usually not more than 4.2 $\mu$  thick. The basidia in old regions are often very irregular in shape. Entire top layer 92–262 $\mu$  thick, the thickness depending upon age, hymenium 60–100 $\mu$  thick, hyphae of top layer 2.2–3.5 $\mu$  thick. Spores white, smooth, bent-elliptic, 3–4 x 10–17 $\mu$ , becoming one to three times septate.

Symbiotically associated with scale insects (*Chionaspis gleditsiae* Sanders ?), some of which are parasitized by irregularly coiled haustoria while others are not parasitized.

This species is closely related to *S. Schweinitzii* Burt. The two plants are associated with the same scale insect (*Chionaspis gleditsiae* Sanders ?), but on different host plants, and the hymenial, basidial, and spore characters are much the same except for the smaller size of the basidia and spores in *S. lilacinoalbum*. The two plants may be easily distinguished. The color of *S. lilacinoalbum* is very distinct,—white with a lilac tint when fresh. The present species, moreover, is thinner than *S. Schweinitzii*. Finally the marginal characters of the two are quite different. In *S. Schweinitzii* the margin of the subiculum shows the characteristic "tent-like" elevations, while in *S. lilacinoalbum* the corresponding region is characterized by the pillars, the tops of which spread out like umbrella tops.

This species is almost certainly a hybrid formed by the crossing of *S. Schweinitzii* and *S. Cokeri*. It was first looked upon as a distinct species closely related to *S. Schweinitzii* but with the discovery of abundant material in Chapel Hill it has been possible to follow this fungus for several years during which time its hybrid nature has become quite evident. On the same tree there are a few small patches of *S. Cokeri* but no *S. Schweinitzii*. I have found several pieces (Nos. 9327 and 9384) which were colored exactly like typical *S. Schweinitzii*, benzo brown with the same mottled effect toward the margin. In these specimens which otherwise looked so much like *S. Schweinitzii* there were pillars on the margin instead of the "tent-like" structures. Usually, however, the whitish color predominates over the benzo brown. The pillars predominate over the "tent-like" marginal structures though in some places very rudimentary tent-like structures are formed. In *S. Schweinitzii* the subiculum is densely covered with upright hyphae which are curved above like a shepherd's crook; while in *S. Cokeri* the threads of the subiculum are nearly all horizontal but at the bases of the pillars there are tufts of threads covered with crystals. In the hybrid these two characters are mingled, the subiculum being covered with more or less upright encrusted threads. In *S. Schweinitzii* the sterile threads in the hymenium are vertical and slightly wavy; in *S. Cokeri* the sterile threads are recurved and neither vertical nor wavy. In the hybrid the sterile threads are vertical but much more wavy than in *S. Schweinitzii*, and are frequently coiled. In both *S. Schweinitzii* and the hybrid the sterile threads of the hymenium anastomose freely but not in *S. Cokeri*. In reproductive structures the coiled basidial characters of *S. Schweinitzii* dominate over the probasidial and basidial characters of *S. Cokeri*, i.e. in the hybrid species the probasidium is

usually lacking and the basidium is coiled as in *S. Schweinitzii*. The "probasidial cell" character is latent however, since quite frequently a type of probasidial cell about the same size and shape as in *S. Cokeri* may be formed from any one of the basidial cells. The spores are shaped like those of *S. Schweinitzii* but are considerably smaller in the material from Highlands, N. C.

Specimens examined:

North Carolina: Type near Highlands, N. C. on *Hicoria alba*, August 6, 1931. Else R. Couch, coll., 9064; Chapel Hill, near Laurel Hill on *Hicoria glabra*, October 23, 1932, Nos. 9322 and 9327; May 7, 1933, No. 9384, August 24, 1934, No. 9843, and Nov. 26, 1934, No. 9899. Very abundant on this one tree and causing great damage to the tree, having killed over half the limbs. Occurring on the same tree: *S. Mariani*, *S. Curtissii* and *S. Cokeri* and *S. apiculatum*. By marking certain specimens on this tree and following their development through the seasons it has been possible to detect that this fungus passes through remarkable color changes from season to season. During late summer and early fall the color is a beautiful white with a pale lilac tint. Specimens collected in October are pinkish buff. This color becomes darker, passing through wood brown to mummy brown by the last of November. In the spring as new growth begins, the specimens become lighter in color and pure white with the characteristic lilac tint by mid-summer.

South Carolina: Near Jacksonboro on *Hicoria* sp., March 20, 1930.

**Septobasidium tenue n. sp.**

Plates 9 and 37

Fungus body resupinate, very closely adherent to the bark, forming irregular isolated or confluent patches which seldom exceed six to eight cm. in length. Color quite variable, mouse gray or drab or pale gray or with a buff or brownish tint. Surface usually inherently smooth, except for minute depressions and except for very minute cracks in the older regions and irregularities in the bark. Here and there on the surface are numerous, dark, elevated areas beneath which are parasitized and non-parasitized scale insects; in old specimens these elevated dots may not be evident. Margin irregular in outline; determinate. In section about  $100\text{--}225\mu$  thick, usually about  $125\mu$  thick, in very young regions not more than  $25\mu$  thick; compact, often stratose (no. 9183) in old regions, a new hymenial stratum forming each year (no. 8456 not stratose). Context composed of much entangled, branched, septate, mostly hyaline threads, without clamp connections; threads heavily

encrusted with crystalline material; tips of threads at surface often bent like a shepherd's crook;  $3.2\text{--}4.2\mu$  thick; probasidia absent unless the sometimes thick-walled resting cells of the basidia may be considered as such. Basidia  $6.3\text{--}7.5 \times 29\text{--}37\mu$ , up to  $50\mu$  long when nearly straight, but nearly always coiled and twisted, 4-celled, each cell usually giving rise to a sterigma on the end of which is formed a spore. Spores (of no. 8456) bent-elliptic, dividing into 4 or 8 cells,  $2.5\text{--}4.2 \times 13\text{--}22\mu$ , most  $3.2 \times 16.8\mu$ .

Associated with *Aspidiota juglans-regiae* Comst. on bay and *Aspidiotus* sp. on oak, some of the insects being parasitized by haustoria which are in the form of miniature strings of sausages.

Very puzzling color variations occur in this species, sometimes even in the same collection. Number 8456 from South Carolina was growing on oak. In this lot of material of which there are over thirty patches of growth there is one patch nearly pure white which upon examination was found to be *S. apiculatum*. This latter species is also exceedingly thin and differs macroscopically from the species under consideration only in color and in the structure of the insect houses. The patches of growth in this collection vary in color from a drab gray to very light gray. In the lighter patches a microscopic examination shows the presence of thin-walled hyaline hyphae characteristic of *S. apiculatum*. Some of the color variation in this collection may possibly be due to the mixed growth of the mycelium of these two species.

This species may usually be recognized by the drab color, the small circular, dark elevations; and the coiled basidia. In No. 8456 there were large numbers of living algal cells embedded in the hymenial layer of the fungus.

#### Specimens examined:

South Carolina: Near Charleston, on *Quercus*, March 19, 1930, J. N. Couch, coll., 8456. Type.

Florida: Kissimmee, on *Quercus nigra*, March 13, 1932, J. N. Couch, coll., 9243, 9246; also near Gainesville, on *Quercus nigra*, Feb. 22, 1935, G. F. Weber and E. West, colls., Univ. Fla. Herb., 9965.

Mississippi: Near Pascagoula, on *Magnolia virginiana*, Jan. 1, 1932, J. N. Couch, coll., 9183, 9185, 9187, 9188, 9214.

#### *Septobasidium rugulosum* n. sp.

#### Plates 9 and 36

Fungus body resupinate, closely adherent to the bark, forming small (2-3 x 4-5 cm.) irregular, isolated or confluent patches. Color tawny

olive to sepia. Surface minutely retiform, often with dark, circular dots beneath each of which is, as a rule, a parasitized or healthy scale insect, surface rarely nearly smooth. Margin at times abruptly determinate, more often minutely fibrillose. In section 60–250 $\mu$  thick, compact, composed of a basal region of thick-walled, brownish, septate threads, which are deeply constricted at the septa, threads 4–10.5 $\mu$  thick. These threads when crushed separate into short segments. Upper region composed of the same type of threads except smaller; tips of threads at surface often bent like a shepherd's crook, surface threads covered with crystalline material. Probasidia absent. Basidia 4–5 $\mu$  wide, about 35–42 $\mu$  in length (allowing for the curvature); twisted or coiled, 4-celled, each cell giving rise to a sterigma and a spore; sterig mata often very long; basidia usually difficult to see in section. Spores 3.9–4.6 x 12.6–18.9 $\mu$ , most 4 x 14 $\mu$ , rarely 5 x 21 $\mu$ , bent-elliptic, becoming once or thrice septate.

Associated with *Chionaspis gleditsiae* (?), some of which are parasitized by haustoria which are in the form of strings of sausages.

The adult insects in the material collected March 11–20, 1932, were giving birth to young and consequently a splendid opportunity was afforded for some observations on the fungus-insect relationship. The adult insects are beneath the fungus against the bark, each one in a sort of chamber, the roof and walls of which are formed of fungus material and the floor of which is formed by the bark. It is impossible to detect the presence of the insects beneath the fungus except by a very careful examination. If one examines the surface of the fungus with a hand lens or binocular microscope, one may see numerous, small slits, shaped like a new moon. These slits are the openings or doorways to the insects' chambers. At the time the material was first examined the adults had already given birth to large numbers of young. The young emerge through the slit openings, crawl about over the top of the fungus for a while and then settle down on top of the fungus, as a rule picking out the depressions between the ridges. The insects give off something which causes a profound change in the fungus in their immediate vicinity. After a few days, but before the insect has excreted its first scale, the fungus becomes lighter in color beneath and around the young insect. A few days later the insect has excreted its first scale and the fungus around the insect has become almost black in color. The insects are so abundant that the surface of the fungus at this time is literally peppered with these dark dots. After about two weeks the fungus beneath the insects has completely disappeared so that the insects are against the bark. As the insects sink down into the fungus new

growth begins at the surface, the threads extending over the insect so that it eventually becomes completely covered by the fungus.

Some of the living insects examined after the first moult showed the fungal haustoria within their bodies. I suspect that infection here takes place much as in *S. Burtii* and that the spores furnish the source of infection. I have been unable, however, to demonstrate this. I have examined ten young which were crawling about over the sporulating surface and although spores could be seen on the surfaces in the insects' bodies, I was unable to find any infecting cells within their bodies.

This species occurs in the same region with *S. tenue* and sometimes on the same tree and is very closely related to that form. Generally the two species may be separated by color, *S. tenue* being drab (Ridgway) while *S. rugulosum* is a rich brown (tawny olive to sepia of Ridgway). The surface of *S. rugulosum* is generally retiform while that of *S. tenue* is inherently smooth. The surface of *S. tenue* generally shows numerous, dark, elevated mounds beneath which are scale insects, whereas in *S. rugulosum* the surface of the fungus immediately over the insects is not elevated. The surface of the latter, however, is dotted with the minute dark specks which form beneath the young scale insects. In microscopic section the two species are quite similar. Both have coiled basidia but those of *S. tenue* are shorter and thicker than are those in *S. rugulosum*. The spores are quite similar in shape but differ in size, those of *S. rugulosum* being slightly thicker and shorter. The threads in the context of the two plants are quite dissimilar. Those of *S. rugulosum* are composed of short segments, the threads showing rather deep constrictions at the joints. When a mass of these threads are crushed, they separate into short joints. The threads also are generally coiled and twisted. In *S. tenue* the threads are composed of long, more or less straight, segments, are not constricted at the joints and do not separate into short segments when crushed.

#### Specimens examined:

South Carolina: Jacksonboro, on *Liquidambar styraciflua*, March 20,

1930, J. N. Couch, coll., 8472, type; near Myrtle Beach, on *Liquidambar styraciflua*, July 4, 1928, J. N. Couch, coll., 8314.

Florida: Jacksonville road near Ga. line, on *Liquidambar styraciflua* associated with *Chionaspis gleditsiae*, March 11, 1932, 9229; near Kissimmee, on *Magnolia virginiana*, March 13, 1932, J. N. Couch, coll., 9251; also 9244.

Louisiana: Near Baton Rouge, on *Quercus* sp., Dec. 31, 1931, J. N. Couch, coll., 9154.

**Septobasidium canescens** Burt. Ann. Mo. Bot. Gard. 3: 342, fig. 13. 1916.

Plates 7 and 38

Fungus body resupinate, covering several square centimeters on the bark of *Quercus*. Pale olive buff, the olive color due to the presence of algae mixed among the hyphae. Surface irregular, due to numerous bumps and cracks, cottony in places. Margin thin but determinate. In section 450–1,000 $\mu$  thick, not differentiated into layers. Hyphae in the subiculum rather closely packed and extending more or less horizontally from the subiculum; the hyphae arising obliquely to form the loosely woven branched threads of the context; hyphae 3–5 $\mu$  thick, hyaline, septate, without clamps. In the older parts the hyphae are thick-walled, much septate, and constricted at the joints. Hymenial region irregularly arranged, not forming a distinct layer, composed of probasidia and basidia in various stages of development. Probasidia spherical, 10.5–19 $\mu$ , usually 15–16 $\mu$  thick, basidia arising from the probasidia which are left as empty cells. Basidia 9.2–10.5 x 50–63 $\mu$ , thickest at the distal end, divided at maturity into 2, 3, or 4 cells by transverse walls. Usually three-celled, the distal cell being much larger than the proximal two cells. The basidia are typically very irregular in the material examined by me and very few have any sterigmata. Usually the 2 or 3-celled basidia have thickened walls—an adaptation perhaps to development in dry climate. Spores 6.3–9.6 x 18–21.8 $\mu$ , hyaline, bent-elliptic.

Associated with scale insects, some of which are parasitized by irregular coils while others are free from infection.

This fungus may be recognized by the whitish, irregular, cottony surface (under lens), the lack of pillars, the spherical, hyaline probasidia, and the irregular basidia. The mycelium and the irregular basidia suggest a relationship to *Septobasidium apiculatum*.

Specimens examined:

California: Part of type in Farlow Herbarium, 1915; Pasadena, on *Quercus*, A. G. Smith, June 15, 1914; same location, March 13, 1915; Tustin, March 1921, on *Quercus agrifolia*, H. S. Fawcett, coll.; Pasadena, Dec. 22, 1933, on *Quercus agrifolia*.

**Septobasidium apiculatum** n. sp.

Plates 12 and 39

Fungus body resupinate, forming rather inconspicuous, small, more or less circular or irregular patches on living bark, up to 5 x 10 cm. in

area; typically sordid white in color, when fresh, sometimes with a fleshy or buffy tint. Surface inherently finely granulose but with numerous bumps and irregularities partly due to the roughness of the bark, also with numerous mounds on the top of each of which is a single spine about 1.5 mm. high, mounds up to 1.5 mm. wide. In section 250–550 $\mu$  thick in well developed specimens, usually about 275 $\mu$  thick, compact, often stratose due to the formation of successive hymenial layers. Threads of context 4–5 $\mu$  thick, septate, constricted at joints, without clamp connections. Probasidia thin-walled, hyaline, ovoid, elongating and enlarging to form the basidia. Basidia elongated, club-shaped, 6.8–8.4 x 23–32 $\mu$ , 3-celled, each cell giving rise to a long sterigma on the end of which a spore is formed. Spores 4.6–6.3 x 13–25 $\mu$ , most about 5.4 x 17.8 $\mu$ , bent-elliptic. Haustoria composed of elliptic cells held together by very fine threads.

Symbiotically associated with several species of scale insects, the species depending upon the host plant. In such an association some of the insects are parasitized by spindle-shaped hyphae while others are left free to reproduce. On *Cornus amomum*, associated with *Aspidiotus aencylus* which are parasitized through the body wall by the mouth, also sometimes associated with *A. juglans-regiae* and *A. forbesi*. Large numbers of the two species *Chrysomphalus tenebricosus* Comst. and *Parlatoria proteus* are present beneath the fungus on *Cornus amomum*, but none are parasitized. On sweet bay (*Magnolia virginiana*), associated with *Aspidiotus diffinis* Newst. and on pin oak (*Quercus palustris*), associated with *A. osborni* New. & Ckll.

Easily recognized by the thin white growth with the upright fascicles of hyphae.

This species is abundant in the Coker Arboretum and since the material was easily obtained some observations have been made to determine some of the details in the fungus-insect relationship. The observations were made mostly on material on *Cornus amomum*.

It has been determined that the fungus is perennial. In fact several patches of fungus growth have been marked and kept under observation since 1928. At all times during the year it is possible to find living, healthy scale insects beneath the fungus. The association between the insect colony and the fungus is therefore of a permanent nature depending only upon the life of the tree or shrub.

During winter the probasidial cells of the fungus are formed. Except for this activity the fungus is dormant. During this period there are vast numbers of healthy overwintering females and a few males beneath the fungus. There are also a considerable number of parasitized insects beneath the fungus but such insects are much less abundant during the dormant than during the growing season.

With the coming of the warm rains of spring, the fungus starts growing and fruiting and the overwintering female insects, which have been impregnated some weeks earlier, begin giving birth to young. Whereas the spores are formed only during damp warm weather, the young insects crawl out at all times though they appear to be more abundant on cloudy, warm days.

The fungus appears to have a chemotactic attraction for the insects, for though they are free to settle down where they will by far the greater number settle down on the surface of the fungus rather than on the bark. This is all the more remarkable in view of the fact that the young when not associated with the fungus normally seek some crack or shelter under the bark. I have been unable as yet (May 25, 1932) to determine if the young are infected by spores or if they are congenitally infected.

A few days after the young settle down their bodies become completely covered by the white pellicle (white in *A. ancylos*) excreted by the insect. In a few days more the fungus begins to grow up around the insect on all sides, forming a sort of circular pen around the latter. The insect continues to increase in size. After a week to ten days the fungus has almost completely disappeared beneath the insect, digested by enzymes excreted by the insect or worn away by the movements of the latter, and thus the insect comes to lie directly on the bark. Meanwhile the fungus continues to grow upward over the insect's scale, forming finally a mound-like covering on the top of which is one or more long vertical peaks. The ceiling of the fungal house is formed by the insect's scales which are so thoroughly overgrown by the fungus that they adhere firmly to it, and the floor of the house is the bark. The insects, therefore, are nowhere in contact with the fungus.

There are several species of small parasitic hymenopterous wasps which prey on this scale and the insects in the fungal houses are partly protected from such enemies.

Other insects which settle down on the fungus become parasitized by it. Why some are parasitized while others are free from infection, I cannot say as yet. The parasitized insects are covered by a comparatively very thick mat of fungal hyphae, which, though completely surrounding the insect, is not closely pressed to the latter except around the mouth area. Such insects contain numerous tufts of haustoria which are in the form of spindle-shaped cells held together by fine threads. The hyphae which connect the haustoria with the fungal pad pass through the insects' derm by the mouth. The parasitized

insects live longer than the healthy ones though the former are incapable of reproducing.

Specimens examined:

Virginia: Mecklenburg Co., on *Cornus florida*, with *S. filiforme*, 8179.

North Carolina: Chapel Hill, on *Cornus florida* and *C. amomum*, common at all times of the year, twenty-seven collections; on *Hicoria* sp. 9323; on *Quercus phellos*, March 11, 1929, 8390, type; on *Quercus palustris*, 8492; on *Liquidambar styraciflua*, 9334; on *Pyrus japonica*, 9078; on *Carpinus caroliniana*, 9391; on *Cercis canadensis*, 9386, 9387; near Raleigh, on *Cornus florida*, May 15, 1929, B. B. Fulton, coll., 8410; Pasquotank County, on *Cornus florida*, Willard Hewitt, coll., 9366.

South Carolina: Near Charleston, on *Quercus*, March 19, 1930, J. N. Couch, coll., 8459; St. Helena's Island, on *Liquidambar styraciflua*, March 21, 1930, 8486; on *Magnolia virginiana*, March 21, 1930, 8484.

Florida: Near Brooksville (host ?), March 17, 1932, J. N. Couch, coll., 9280; near Tallahassee, on *Liquidambar styraciflua*, March 17, 1932, J. N. Couch, coll., 9281.

Louisiana: Near Baton Rouge, on *Liquidambar styraciflua*, Nov. 21, 1932, C. A. Brown, coll., 567, and U. N. C., 9952.

Arkansas: Near Little Rock, on *Quercus phellos*, April 12, 1933, Dow V. Baxter, U. N. C., 9377.

**Septobasidium sinuosum n. sp.**

Plates 8 and 29

Fungus body resupinate, often covering an area 20 cm. long by two or more centimeters wide. Surface repeatedly divided by irregular, sinuous, anastomosing ridges, especially toward the margin and often throughout; sometimes nearly smooth in the center with a few minute holes; old areas often becoming cracked; pallid mouse gray or pallid purplish gray to Quaker drab or purplish gray, sometimes with dark dots here and there. Margin thin, whitish, myceloid. In section 400–600 $\mu$  thick, composed of three rather indistinct regions or layers: (1) the subiculum, a thin inconspicuous layer (about 20 $\mu$  thick) which grows horizontally over the surface of the bark, threads of subiculum about 2.2 $\mu$  thick, hyaline in regions or deep mouse gray to sordid purplish brown; (2) middle layer concolorous with the subiculum, usually 300–400 $\mu$  thick, composed of rather loosely packed, nearly dichotomously branched, entangled hyphae; hyphae 2–2.4 $\mu$  thick, hyaline or brownish under the microscope, often with dark colored hyphae intermingled with hyaline threads, without clamp connections, peculiar in

that under an oil immersion lens the walls are distinctly warty, punctate or spiny; (3) hymenial layer, which is usually hyaline, 50–120 $\mu$  thick, composed of very densely packed, twisted and much entangled hyphae, the ends of which are slightly coiled, probasidia and basidia in various stages of development. Probasidia spherical or slightly subspherical, 5.8–7.2 $\mu$  thick, germinating to form a cylindrical basidium, the probasidium becoming entirely empty during the process. Basidium 3.8–4.4 x 20–32 $\mu$ , becoming once septate by a transverse wall, each cell of the basidium sprouting a long sterigma which grows to the outer surface of the hymenium and there bears a spore. Sterigmata 18–25 $\mu$  long. Spores smooth, sausage-shaped, 4–5 x 11.5–16.8 $\mu$ , most 4.2 x 12.6 $\mu$ .

This species shows a great variation in color, sometimes being very light colored, nearly white, and at other times a very deep, dull purplish brown. It can readily be recognized by the peculiar surface which is divided up by anastomosing, sinuous ridges as in some crustaceous lichens. This species has been confused with *S. Langloisii* (for a comparison of the two see under *S. Langloisii*).

Associated with scale insects, some of which are parasitized by peculiar sausage-shaped hyphae while others are free from parasitism.

Very common (represented by 41 collections) from southeastern North Carolina southward along the coastal region and westward to New Orleans and perhaps farther.

#### Specimens examined:

North Carolina: Near Wilmington, on *Carpinus caroliniana*, Dec. 30, 1921, J. N. Couch and F. A. Grant, colls., 4955; near Wilmington, on *Liquidambar styraciflua*, Dec. 28, 1922, Couch and Grant, colls., 5934; near Magnolia, on *Cornus florida*, in fruit, Jan. 1, 1928, A. C. Mathews, coll., 8301, type.

South Carolina: Lynch's river bottom, near McBee, on *Liquidambar styraciflua*, June 30, 1928, A. B. Couch, coll., 8316; also on *Ilex opaca*, J. N. Couch, coll., 8321; near Georgetown on *Myrica carolinensis*, July 2, 1928, J. N. Couch, coll., 8322; near Georgetown, on *Quercus phellos*, July 3, 1928, 8323 A; Myrtle Beach on *Quercus nigra*, August 29, 1931, associated with *Aspidiotus osborni*, J. N. Couch, coll., 9099.

Florida: Very abundant as far south as Sebring. Near Jacksonville, Kissimmee, Brooksville, and Tallahassee, J. N. Couch, coll.; on *Quercus laurifolia*, Gainesville, G. F. Weber, coll., 9410, 9964; also Gainesville, H. E. Stevens, coll., Mo. Bot. Gard. Herb., 44211, under *S. Langloisii* Pat.

Mississippi: Pascagoula, common on several species of *Quercus*, *Cornus florida*, *Liquidambar*, also a variety on *Magnolia virginiana*, with a nearly smooth not sinuous (or only slightly sinuous in places) surface, somewhat cracked in older parts. Color dark vinaceous gray. Probasidia, basidia, and spores smaller than in type. Spores  $3-4 \times 10-13.8\mu$ . Jan. 1, 1932, J. N. Couch, coll.

Louisiana: New Orleans, on *Liquidambar styraciflua*, Dec. 31, 1932, Donald Rogers, 9935; Baton Rouge, on *Liquidambar styraciflua*, Jan. 8, 1932, Clair A. Brown, 9705; also 9706 from same locality on *Quercus nigra*; and 9178 on vine (*Aristolochia*?) Dec. 31, 1931, J. N. Couch.

**Septobasidium Langloisii** Pat. Bull. Soc. Myc. Fr. 16: 54. 1900.

Plates 8 and 41

Fungus body resupinate, covering very extensive areas, sometimes up to several square decimeters in extent, on the main stem and branches of a variety of trees. Color pale violet plumbeous (Ridgway), or about grayish blue. Surface usually very irregular, retiform or with conspicuous cracks in the older areas, rarely nearly smooth or with minute holes. Margin usually determinate and with conspicuous rhizomorphs. In section  $400-500\mu$  thick, compact except for tunnels which are abundant in the younger parts. Context  $330-420\mu$  thick, composed of rather loosely packed, much branched, entangled, brown, septate threads, without clamps,  $2.8-3.8\mu$  thick, often swollen. Hymenium  $60-80\mu$  thick, composed of brownish threads which branch out to form very thin (about  $1.5\mu$  thick) hyaline upright threads and probasidia and basidia in various stages of development. Probasidium  $8.4-12.6\mu$  thick, spherical or slightly subspherical, germinating to form a somewhat ovoid basidium, and remaining as an empty cell at the base of the basidium. Basidia 2-celled,  $6.7-12 \times 21-29\mu$ , most about  $8 \times 23\mu$ , usually thickest in the middle part, sometimes thickest in the distal half; sterigmata  $10-25\mu$  long, borne on both cells of the basidium. Spores elliptic, flattened on one side, sometimes pointed at each end,  $6-8.4 \times 13.8-21\mu$ .

Symbiotically associated with scale insects (*Aspidiotus* sp.) some of which are parasitized by hyphae composed of spindle-shaped segments connected by very fine threads, some of these threads being more or less straight while others are irregularly coiled. Other insects are free from parasitism and are in all stages of development.

This fungus may be distinguished by its color, the absence of pillars, and by the peculiar marginal and surface characters. Some of the specimens are remarkably beautiful in color and symmetry. The fungus has doubtless been passed over as a crustose lichen.

*Septobasidium sinuosum* n. sp. has been confused with this species. Both species occur abundantly in the Gulf States but while *S. Langloisii* occurs only in the Gulf States, *S. sinuosum* extends as far north as southeastern North Carolina. Though the two species may easily be confused, they are quite distinct. *S. sinuosum* is usually lighter in color being a pallid mouse gray or when darker, quaker drab to purplish gray, while *S. Langloisii* is usually pale violet plumbeous. The two may also be distinguished by the surface characters, *S. sinuosum* having a distinctly bumpy and sinuously ridged surface, the ridges being rounded; *S. Langloisii* also has a surface with ridges but the ridges are not so distinct, and their surfaces are more flattened and their margins are not rounded but appear to have been eaten away. The margin of *S. sinuosum* is usually without conspicuous rhizomorphs, while in *S. Langloisii* the dark colored rhizomorphs are quite distinct. Microscopically the two are distinct. In *S. sinuosum* the probasidia are 5.8-7.2 $\mu$  thick, the basidia 3.8-4.4 x 20-32 $\mu$ , the spores 4-5 x 11.5-16.8 $\mu$ ; in *S. Langloisii* the probasidia are 8.4-12.6 $\mu$  thick, the basidia 6.7-12 x 21-29 $\mu$ , spores 6-8.4 x 13.8-21 $\mu$ . Thus in *S. Langloisii* the probasidia, basidia, and spores are distinctly larger than in *S. sinuosum*.

This species is common on the Gulf Coast and in Florida, apparently being limited in its American distribution to this region. Usually found on *Magnolia virginiana*, but also occurring on *Fraxinus*, *Carpinus*, *Nyssa*, and a few other trees. Often found on the main trunk near the base as well as on the limbs.

#### Specimens examined:

Louisiana: Type, near St. Martinsville, on *Crataegus arborescens*, May 11, 1899, Langlois, 2995, in Patouillard Herb., Harvard, fertile; near Baton Rouge, on *Crataegus*, Dec. 31, 1931, J. N. Couch, 9172.

Mississippi: Pascagoula, very abundant on *Magnolia virginiana*, Jan. 1, 1932, J. N. Couch, 9186, 9194, 9195, 9196, 9198; also near Ocean Springs, June 1896, in N. Y. Bot. Gard. Herb.

Florida: Daytona, Jan. 1898, Thaxter, Farlow Herbarium; Brooksville, on *Carpinus*, very abundant, almost every tree infected, March 17, 1932, J. N. Couch, 9281; Sebring, on *Fraxinus*, March 14, 1932, 9268, also on unidentified trees, 9271, 9272, 9273; near Kissimmee, on *Fraxinus*, March 13, 1932, J. N. Couch, 9247, also on unidentified trees 9237, 9249; near Tallahassee, on (?), March 17, 1932, J. N. Couch, 9286; near Orlando, on *Magnolia virginiana*, very common, March 12, 1932, 9956; Ichetucknee Springs, near Fort White,

on *Carpinus*, Feb. 1, 1935, Dow V. Baxter, coll., 9967, surface nearly smooth; same locality Feb. 3, L. E. Arnold and E. West, colls., Univ. Fla. Herb., 9939.

Cuba: La Prenda, Dec. 1921, U. S. D. A. Herb., also U. N. C. Herb.

Form with pillars and nodulose surface. Probasidia spherical, 10–12.6 $\mu$ , basidia 2-celled, about 8 x 25 $\mu$ , haustoria typical.

**Septobasidium sabalis n. sp.**

Plates 14 and 40

Fungus body resupinate, spreading about over the surface of the petiole and blade of palmetto leaves, covering an area up to 100 sq. cm. or perhaps more; vinaceous buff to wood brown (Ridgway). Surface smooth, almost shiny. Margin usually determinate but irregular in outline. In section up to 1 mm. thick, composed of (1) a very thin subiculum about 50 $\mu$  thick from which arise short pillars, 80–125 $\mu$  tall, which support (2) another, thicker horizontal layer, 80–125 $\mu$  thick. This second layer is often incompletely developed. Between these two layers the scale insects live. From the bottom layer and sometimes from the second arise the pillars. The pillars pass up through the second layer branching out at their tops to form the third or top layer. Pillars quite inconspicuous, about 15–20 to a square mm., 20–70 x 275–375 $\mu$ , branching out at the top to form a thick region of loosely interwoven hyphae, about 4.2 $\mu$  thick, septate without clamps, this region about 500–600 $\mu$  thick. Hymenium borne on surface of top layer, about 120 $\mu$  thick, composed of much branched, entangled hyphae which are more densely packed than in the underlying context; and probasidia and basidia in various stages of development. Probasidium subspherical or pyriform, 9.6–12.6 x 15–22 $\mu$ , sprouting and emptying its contents to form a cylindrical basidium. Basidium 8.4–9.6 x 42–50 $\mu$ , usually thickest in the distal part, sometimes thickest in the middle, once septate by a transverse wall when mature. Each cell of basidium giving rise to a long sterigma up to 30 $\mu$  long on the end of which is borne a spore. Spores 5.4–8.4 x 19–27 $\mu$ , most 6.7 x 25 $\mu$ , recurved at the distal end, broadest at the mucro end, becoming divided into a number of cells by cross and longitudinal partitions.

Symbiotically associated with *Aspidiotus* (?) *sabalis* Comst., some of which are parasitized by coiled hyphae while vast numbers, in all stages of development, are free from parasitism. The species of scale insect agrees well with Comstock's description of *Aspidiotus* (?) *sabalis*. The scale is snow white and nearly circular. The leaf blades and petioles are remarkably free from the insects except beneath the fungus. In this species the subiculum penetrates the stomatal openings, developing

tufts of hyphae within the openings. These hyphae apparently do not enter the cells.

It may be distinguished from other species by its habit on the *Sabal palmetto*, by having a subiculum and then a second layer a short distance above the subiculum in addition to the usual horizontal top layer. In the possession of three horizontal layers this species resembles *S. Mariani* Bres. The two bottom layers may grow together in old specimens so that only one layer, the subiculum is evident. The narrow pillars and the very thick top layer composed of very loosely woven hyphae are other distinguishing characters. Microscopically, the large two-celled basidium and the irregularly septate spore, recurved at the distal end, may help in identification.

Specimens examined:

Louisiana: Near Baton Rouge, on leaves and petioles of *Sabal Deeringiana*, Dec. 26, 1931, C. A. Brown, coll., 317, also U. N. C., 9151, type; near Denham Springs, on leaves and petioles, *Sabal Deeringiana*, Jan. 10, 1932, C. A. Brown, coll., 325; also U. N. C., 9210; near New Orleans, on leaves of *Sabal Deeringiana*, Oct. 26, 1933, M. L. Bomhard and W. T. Swingle, colls., U. S. D. A. Herb. and U. N. C. Herb., 9959.

**Septobasidium Patouillardii Burt.** Ann. Mo. Bot. Gard. 3: 332. 1916.

Plates 13, 15, 42

Fungus body resupinate, forming irregular patches which are usually rather small but which may be up to 20 cm. in length; snuff brown or sepia to mummy brown or clove brown to blackish brown with a velvety appearance and a purplish tint, the latter combination of colors being the most characteristic. Surface smooth in the younger regions, cracked in the older parts. Margin irregular in outline, sharply determinate, the lower layer usually not extending beyond the top layer. In section 300-460 $\mu$  thick, composed of three regions: (1) the subiculum which extends over the bark and is very thin (about 20 $\mu$ ), composed of interwoven, septate hyphae, about tan colored and contrasting strikingly with the darker top layer; hyphae about 3 $\mu$  thick; (2) a region of very slender, upright pillars which are 20-54 x 140 $\mu$ , hyphae of pillars about 4 $\mu$  thick, branching out toward the top to form (3) the top layer which bears the hymenium. Top layer 100-210 $\mu$  thick, sometimes stratose, the lower part of top layer composed of loosely interwoven, much branched threads which are about 3.5-4 $\mu$  thick; hymenium 28-38 $\mu$  thick, sharply distinct from the rest of the top layer by its much darker color, the darker color being due to the paraphyses; paraphyses vertical,

thick-walled, about  $3.2\mu$  thick. Probasidia absent unless the small, thin-walled, elongated, transitory cell (see figure) which elongates and enlarges to form the basidia may be considered as such. Basidia elongated, 2-celled,  $5.2-5.6 \times 18-23\mu$ , each cell giving rise to a sterigma and a spore, sterigmata  $20-25\mu$  long. Spores  $4.2-5.8 \times 10.9-16.6$ , rarely up to  $21\mu$  long, bent-elliptic, hyaline, becoming thrice septate.

Symbiotically associated with *Chionaspis gleditsiae* some of which are parasitized by very irregularly coiled hyphae, others of which are free from fungal infection. Perennial, the spores forming during spring and early summer.

This species often occurs along with *S. Schweinitzii*, *S. pseudopedicellatum*, *S. Curtisi*, *S. Mariani*, and *S. castaneum*, but may easily be distinguished from any of those on the basis of color and structure. The blackish velvety top surface, contrasting with the lighter (usually tan) colored subiculum, the thinness of the plant body, the minute slender pillars, and the distinct, abruptly determinate margin are macroscopic characters by which the present fungus may be distinguished. The vertical paraphyses in the hymenium and the two-celled basidium without a persistent probasidial cell are the most striking microscopic characters. It is very easy, indeed, to recognize this plant from Burt's description. Burt says, "This species may be recognized by its thin fructification resembling a piece of black velvet, slightly raised from the substratum on such short and slender pillars as to be barely visible without the aid of a lens." However, Burt describes the plant as having probasidia. He states that the material with probasidia was "near a specimen of another species." I have examined a large amount of sectioned material collected in February and March, both just before and during the formation of basidia, and have been unable to find any probasidia as described and figured by Burt. It is my opinion that the probasidia belonged to another species.

I have collected this species in North Carolina, Florida, Mississippi, and Louisiana. Type in Burt Herb.

#### Specimens examined:

North Carolina: Near Pee Dee, on live *Fraxinus*, March 24, 1926; near Wilmington, on *Fraxinus*, with *S. Schweinitzii*, Dec. 28, 1921, J. N. Couch, coll., 5876; near Winston-Salem, on *Fraxinus*, with *S. Schweinitzii*, Oct. 28, 1928, Kenneth B. Raper, coll., 8370, also on *Fraxinus*, with *S. Schweinitzii*, Dec. 27, 1933, John R. Raper, coll.; Chapel Hill, rather common in swampy regions, on *Fraxinus*, Feb.

5, 1929, 8386; also March 8, 1929, 8393, and March 14, 1929, 8396, the last two collections fertile; also same locality, Oct. 28, 1928, 8373 and 8374.

South Carolina: Lynch's river bottom near McBee, on *Fraxinus*, June 30, 1928, A. B. Couch and J. N. Couch, colls., 8319.

Florida: Daytona, R. Thaxter, No. 75b, in Farlow Herb. and Mo. Bot. Gard. Herb., 43895; near Kissimmee, on *Fraxinus*, March 13, 1932, J. N. Couch, coll., 9298, fertile, sepia to clove brown, the fertile specimens slate colored; near Lisbon, on *Fraxinus* (?), Jan. 24, 1891, L. M. Underwood, coll., 2908. Determined by J. R. Weir as *S. fumigatum* Burt? in U. S. D. A. Herb., also fragment in U. N. C. Herb.

Louisiana: St. Martinsville, A. B. Langlois, 3005, type, in Burt Herb.; near Baton Rouge, very abundant on *Ilex decidua*, 9168, and 9170, on *Fraxinus* Dec. 31, 1931, J. N. Couch, coll., 9169; on *Gleditsia triacanthos*, with *S. pseudopedicellatum*, Dec. 31, 1931, J. N. Couch, coll., 9161.

### Septobasidium grandisporum n. sp.

#### Plates 5 and 43

Fungus body resupinate, forming extensive patches on the living bark of dogwood, often girdling the trunk for a height of several decimeters. Hymenium usually pale smoke gray (Ridgway) when well developed, vegetative parts brownish black. Surface spongy except where the hymenium is well formed, then with numerous cracks and holes; even the smoothest places are distinctly bumpy under a lens. Margin usually determinate, often with distinct rhizomorphs. In section up to 2.5 mm. thick, composed, in mature specimens, of the hymenial region and the context but with no distinct subiculum. Context composed of rhizomorphs which extend about over the bark, from which a vast tangle of fascicles of hyphae arise, giving the context a spongy texture. Hyphae of context much branched, septate, without clamp-connections,  $3 \times 4.2\mu$  in diameter. Hymenial region  $150-250\mu$  thick, composed of more or less upright, much branched, hyaline and brownish hyphae,  $3-3.5\mu$  thick, and probasidia and basidia in various stages of development. Probasidium usually slightly subspherical,  $12-17\mu$  thick, sprouting and emptying its entire contents to form the basidium. Basidium long-cylindrical, often curved, thickest at the distal end,  $8.4-9.6 \times 46-56\mu$ , giving rise to an apical sterigma,  $8-22\mu$  long, on the end of which is borne one spore. Spores elliptic,  $12.6-17 \times 29-32\mu$ , most about  $16.8 \times 29.5\mu$ , becoming irregularly septate into a number of cells, hyaline at first but becoming brownish if kept on slide for several days.

Symbiotically associated with *Chrysomphalus obscurus* (Comst.), some of which are parasitized by hyphae which are in spindle-shaped segments (as in *S. fumigatum*) and others of which are free from parasitism. Both parasitized and healthy insects, the latter in all stages of development, are very abundant beneath the fungus.

This species is apparently very rare, having been collected but once, and then on two trees of *Cornus florida* in woods by highway about 30 miles north of Charleston, S. C., March 19, 1930, Else R. Couch, collector. The fungus was very abundant on the infested trees and both trees were very unhealthy, there being a number of dead limbs and other living ones growing in the form of witches' brooms. As in other species the fungus does not penetrate into the wood, the injury being done by the insects.

This species may be confused with *S. fumigatum* Burt, which occurs in the same locality and sometimes on dogwood. They look considerably alike to the naked eye, both have a grayish hymenium and spongy context. In *S. fumigatum* the context is brownish, the hymenium mouse gray and the plant has a smooth, velvety feel. In the present species the context is brownish black, the hymenium smoke gray, and the surface of the plant has a distinctly rough or coarse feel. The haustoria in the two plants are alike but the probasidia, basidia, and spores are distinct.

#### Specimen examined:

South Carolina: About 30 miles north of Charleston, on two trees of *Cornus florida*, March 19, 1930, Else R. Couch, coll., U. N. C. Herb., 8465, type.

**Septobasidium pilosum** Boedijn and Steinmann. Arch. Theecult. 4: 48. 1930.

#### Plates 7 and 18

This remarkable species described from Java on tea has recently been found in Florida on *Mangifera indica* and in Louisiana on *Magnolia virginiana*.

Fungus body resupinate, forming cushion-like patches of growth 1–10 mm. wide by 1.5 mm. high. Color deep brown. Surface minutely setose; margin determinate. In section not divided into layers, about 0.8–1.5 mm. thick. In the basal region rather few, thick hyphae extend over the surface of the bark, penetrating into the cracks; from these

hyphae arise rather closely packed, entangled, upright and mostly straight, frequently septate, dark colored, unbranched threads,  $6-10\mu$ , usually about  $8.4\mu$  thick. In the type these upright threads may be single or several may arise together, forming a small loose fascicle  $10-50\mu$  thick; threads of type  $5-8\mu$  thick, tips of threads hyaline. From the sides of the hyphae, particularly in their basal parts, just below the septum, are borne clusters of conidia, the individual cells of the cluster are hyaline at first but later become dark and thick-walled,  $8-11.7\mu$  thick. The individual cells of the cluster do not separate but the entire mass falls off. On these "multicellular conidia" or conidial bodies a distinct stalk cell is evident; conidial bodies irregular in shape but usually rounded,  $25-65\mu$  thick. Probasidia not formed in material from Florida but in the type material the probasidia are formed on the ends of short septate branches which apparently start off as conidia. Probasidia spherical, sometimes minutely rough, usually  $16.8\mu$  thick but varying from  $12-17\mu$  thick. Germination not seen.

Associated with scale insects, some of which are parasitized by hyphae the main branches of which are composed of spindle-shaped segments held together by fine threads. From these branches numerous coiled masses of spindle-shaped cells connected by fine threads arise. The sausage-shaped haustoria are connected with the external fungus through the derm pores as in *S. Burtii*.

The material from Florida differs from the type in having thicker hyphae and in the fact that the upright hyphae arise singly and not in fascicles as frequently happens in the type. Also the Florida material lacks the probasidia. Except for these slight differences the two fungi are strikingly alike. The basidia have not yet been found but the presence of the very highly specialized and distinctive haustoria typical of certain other species of *Septobasidium* is sufficient evidence that the two collections belong to that genus. The collection from Louisiana on *Magnolia virginiana* is producing probasidia, though I was unable to find any basidia. In color and other characters it resembles the type. The conidial form of *Septobasidium* studied by Petch (Trans. Brit. Myc. Soc. 11: 62-65, 1926) on tea from Formosa also doubtless belongs here, as suggested by Boedijn and Steinmann (1930).

#### Specimens examined:

Java: Type, on tea, Steinmann, coll.; on *Artobotrys*, Dakkus, coll.

Formosa: On tea, Yaizw, Province Sugura, K. Hara, coll., studied by Petch.

Louisiana: Near Baton Rouge, on *Magnolia virginiana*, Dec., 1931, J. N. Couch, coll.

Florida: Delbray, on *Mangifera indica*, May 29, 1934, L. S. Light Jr., coll.; also on *Mangifera indica*, near Oneco, Feb. 12, 1935, Comm. by E. West. With *Leucaspis indica*.

**Septobasidium Peckii n. sp.**

Plate 17

Fungus body resupinate, forming small inconspicuous patches of growth (3 x 6 cm. in the one specimen seen). Tawny to russet or hazel. Surface composed of usually flat, sinuose plates; i.e. the top surface is incompletely formed. Margin determinate but subiculum is indistinct, with a few very inconspicuous (visible only with lens) pillars. In section 500–1000 $\mu$  thick; composed of a very thin subiculum which forms a continuous layer next the bark, from which arise very short pillars the hyphae of which branch out above to form the top layer which may be 500 $\mu$  thick. Hyphae of top layer upright, frequently grouped into columns between which are small spaces, so that the top layer in section has a somewhat spongy appearance. Hymenium immature, composed of upright, closely compacted threads which give rise laterally to the probasidia, the latter being immature. Hyphae of subiculum, hyaline, in younger parts thin-walled, about 3 $\mu$  thick, hyphae of pillars, and subhymenial region pale brownish, 3.8–4 $\mu$  thick, hyphae of hymenium 3.8–4 $\mu$  thick.

Associated with scale insects (*Chionaspis* sp.), some of which are parasitized by irregular coils while others are free from parasitism.

The species is easily distinguished from all others by its striking tawny to russet color, surface appearance, and the peculiar hymenium with the upright threads. The fungus, collected in October, does not show mature fruiting structures but the structure of the immature hymenium and the old hymenium of the preceding spring suggests a relationship to *S. albidum*, which occurs in Ecuador and *S. flavo-brunneum*, which occurs in Java.

Specimens examined:

New York: Near Indian Lake, on living branches of *Alnus incana*, October, Chas. H. Peck. Type in Patouillard Herb., Harvard Univ., labelled *T. pedicellata* Schw.

**Septobasidium sp. hybrid between *S. castaneum* and *S. Patouillardii* (?)**

I have six collections of a species from Louisiana and Alabama which I at first put under *S. Patouillardii* but a more detailed study of these forms has indicated their distinctness from that species.

Fungus body resupinate, forming thin, closely adherent, irregular, confluent, patches up to 10 cm. long. Bister (Ridgway) or slightly lighter. Surface smooth except for the wrinkles in the bark and distinct cracks in older parts. Margin abruptly determinate, the margins of the top and bottom layers usually ending at the same place, irregular in outline. In section 160-520 $\mu$  thick, usually 210-315 $\mu$  thick, composed of three regions: (1) the subiculum which is very thin, 20-70 $\mu$  thick, usually about 40 $\mu$  thick, composed of densely packed threads, 3-4.2 $\mu$  thick, which extend in a more or less horizontal direction, subiculum concolorous with top layer or slightly lighter; (2) the middle region composed of scattered pillars or very thick columns of hyphae, 100-1000 $\mu$  thick and only 50-80 $\mu$  tall, threads of pillars 3.6-4.2 $\mu$  thick, concolorous with threads of subiculum; (3) the top layer supported by the pillars or columns, 55-150 $\mu$ , usually about 65 $\mu$  thick, composed of closely packed and entangled hyphae the ends of which are not arranged vertically but are recurved, hyphae 3.8-4.2 $\mu$  thick, concolorous with the pillars and subiculum. Probasidia and basidia not observed.

Associated with scale insects some of which are parasitized by irregular coils of hyphae.

This species is related to *S. castaneum* Burt, *S. Patouillardii* Burt, and *S. Leprieurii* (Mont.) Pat. From *S. castaneum* it differs in being much thinner, in having a simple margin, in having two instead of three horizontal layers, in having a middle region composed of distinct pillars or columns of hyphae and empty spaces instead of branched pillars and flocculent hyphae. The color of the two is also different, *S. castaneum* showing more of a purplish tint in the brown than the present species. From *S. Patouillardii* Burt it differs in color, being bister without a velvety sheen instead of blackish brown with a faint purplish tint and with a velvety sheen, in having very thick, stubby pillars instead of thin slender ones, in having a subiculum concolorous with the top layer instead of distinctly lighter and in having the ends of the threads in the top layer recurved instead of vertical. From *S. Leprieurii* it differs in having pillars throughout, in being much thinner, and having a tough, crusty texture when torn with a needle instead of a soft, flocculent one. The color of the two species is somewhat similar, though *S. Leprieurii* has a shiny instead of dull surface. *Septobasidium Leprieurii* is also somewhat lighter colored.

This species has so far been found only on *Liquidambar styraciflua*, and although the material is abundant it is all sterile.

Specimens examined:

Louisiana: Near Baton Rouge, Dec. 31, 1931, with *S. Mariani*, *S. pseudopedicellatum*, and *S. castaneum*, J. N. Couch, coll., 9181, 9193; also near Baton Rouge, Dec. 26, 1931, C. A. Brown, coll., 326, U. N. C., 9946; near Covington, Jan. 10, 1932, with *S. castaneum* Burt, C. A. Brown, coll., 321, U. N. C., 9949.

Alabama: Near Nokomis, April 19, 1932, C. L. Shear, coll., in U. S. D. A. Herb. and U. N. C., 9948.

UNIVERSITY OF NORTH CAROLINA,  
CHAPEL HILL, N. C.

## EXPLANATION OF PLATES

The drawings were made by the author and inked in by Miss Alma Holland except the habit sketches and the insects which were inked by the author.

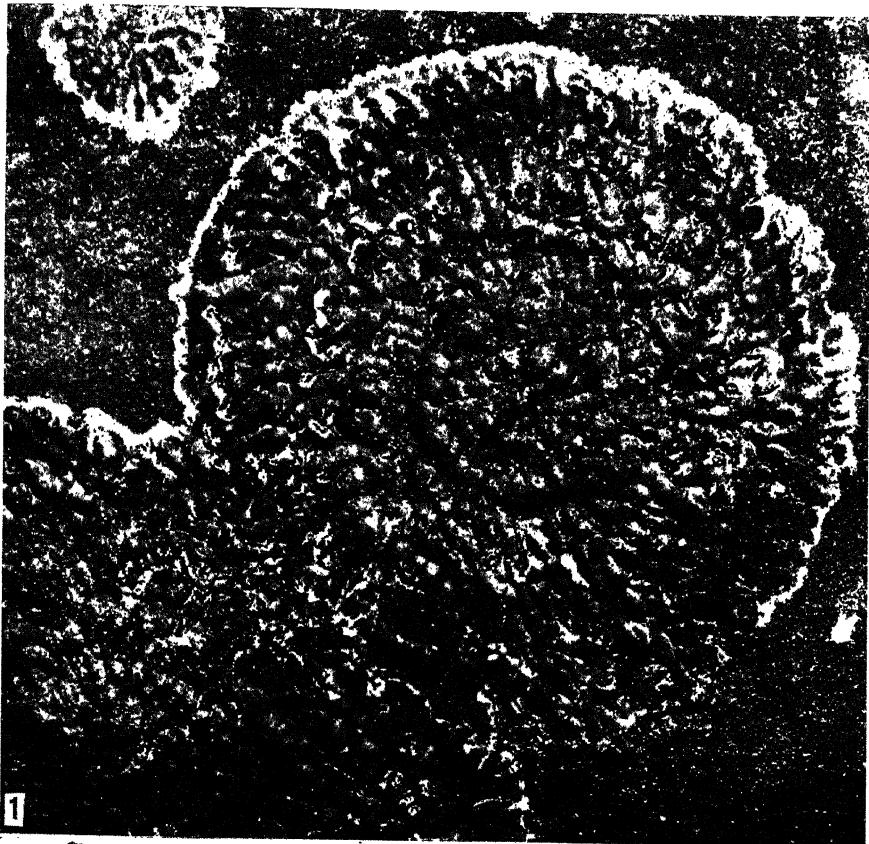
### PLATE 1

*S. Burtii*

Fig. 1. Surface view showing openings to tunnels, radiating ridges and depressions.  $\times 4$ .

Fig. 2. Top layer removed exposing numerous healthy, non-parasitized scale insects.  $\times$  about 11.

PLATE 1



1



2

PLATE 2

Figs. 1-5. *S. alni* Torrend. Figs. 1 and 2 on oak. Fig. 1, No. 8326. Fig. 2, No. 8323. Fig. 3. On *Hicoria pecan* enlarged about one third. Fig. 4. On oak. No. 8353. Fig. 5. A piece of type from Sydow.

Figs. 6 and 7. *S. alni* var. *squamosum* n. var. On oak. Fig. 6, No. 8323 (note *S. castaneum* on lower end of stick). Fig. 7, No. 8325.

Figs. 8 and 9. *S. Leprieurii* (Mont.) Pat. No. 8317. On *Magnolia virginiana*.

PLATE 2



PLATE 3

Figs. 1-5. *S. castaneum* Burt. Fig. 1, type. Slightly enlarged. Fig. 2. On *Ilex americana*.  $\times$  about  $\frac{1}{2}$ . Figs. 3, 4, 5, on *Quercus*. Figs. 3, 4, No. 8339. Fig. 5, No. 9152.  
Figs. 6, 7. *S. Leprieurii* on *Magnolia virginiana*. In fig. 7 note large area<sup>1</sup> of whitish crustose lichen. No. 9299.

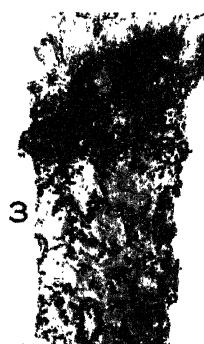
PLATE 3



1



2



3



6



4

7



5



PLATE 4

Figs. 1-5. *S. fumigatum* Burt.

Figs. 6-11. *S. Mariani* Bres. Fig. 10, type. Figs. 6 and 8. On *Pyrus japonica*, spring condition; figs. 9 and 11 also on *P. japonica*, fall condition. In fig. 11 note young scale insects covered by round white pellicle. These hatched beneath fungus, crawling out to settle down on bark. Fig. 7. On *Liquidambar*. Figs. 9 and 11 X about  $2\frac{1}{2}$ .

PLATE 4



PLATE 5

Fig. 1. *S. grandisporum* n. sp., type. On *Cornus florida*.  $\times$  about  $\frac{1}{2}$ .

Fig. 2. *S. Curtisii* (B. & D.) B. & S. On *Nyssa* sp., causing witches' broom.  $\times$  about  $\frac{1}{2}$ .

Fig. 3. *S. Curtisii*. On *Fraxinus americana*. Photographed in August. Note whitish margin of new growth.

Fig. 4. *S. Curtisii* on *Fraxinus*. Early spring condition.

Fig. 5. *S. Burtii*, a variety with nearly smooth surface. On *Prunus*.  $\times$  2.

Figs. 6-8. *S. Sydowii* n. sp. From Philippine Islands, Elmer, coll., No. 14820. Type.

PLATE 5



PLATE 6

Figs. 1-12. *S. Carestianum* Bres. Fig. 1. On *Cornus sanguinea*, France. Pantouillard, coll.

Figs. 2 and 3. On *Salix incana*. Leg. Otto Jaap. Fig. 11. Part of type. The others on *Cornus stolonifera* from Canada. John Dearness, coll.

Figs. 13 and 14. *S. lepidosaphis*. Fig. 13. Material from Cuba, sterile but apparently same as material shown in fig. 14 on *Citrus* from Florida.

Fig. 14. Slightly enlarged.

PLATE 6

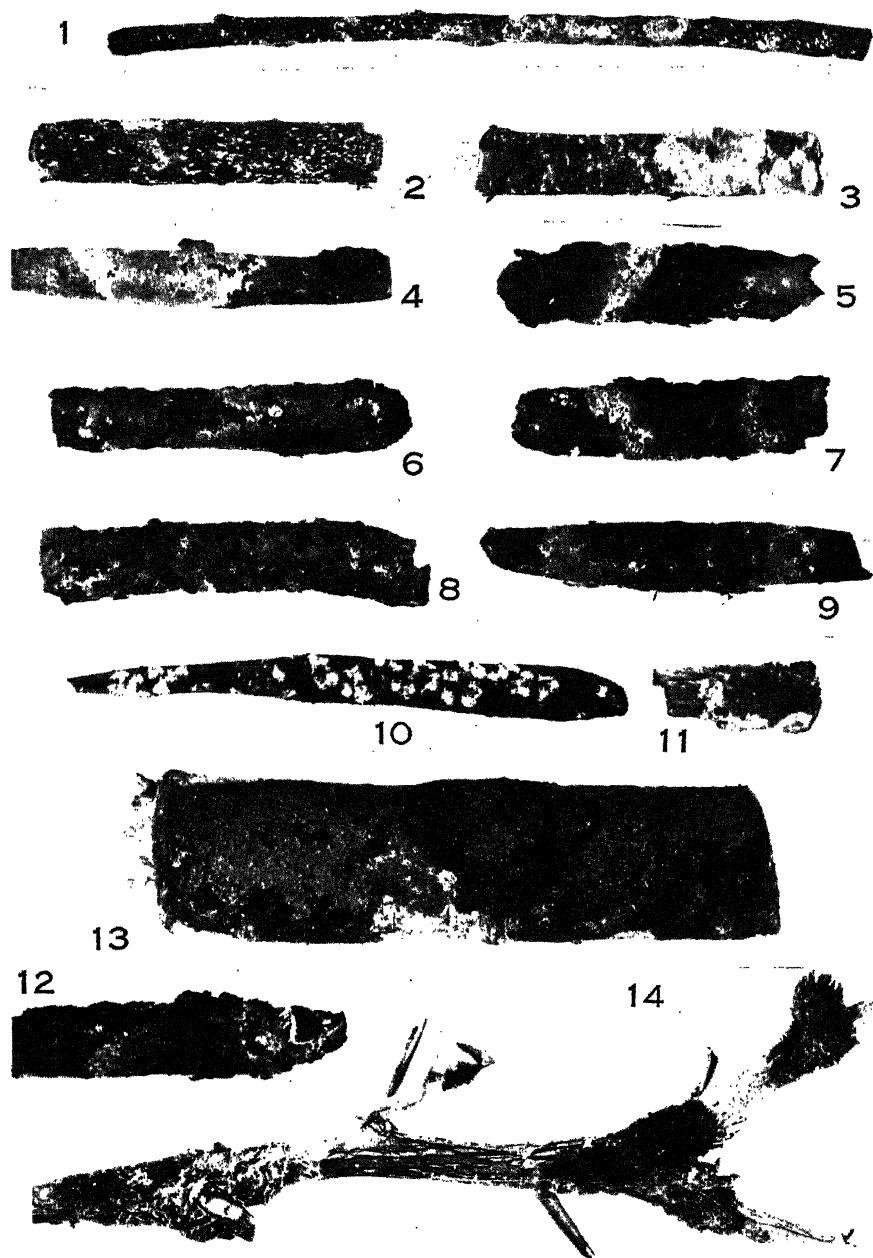


PLATE 7

Figs. 1-7. *S. canescens* Burt.

Figs. 8, 9. *S. pilosum*. Fig. 8 from Florida on *Mangifera indica*; fig. 9, part of type from Java.

Figs. 10, 11. *Septobasidium* n. sp. conidial form on *Citrus* from Florida.

Figs. 12-14. *S. pinicola* Snell.

PLATE



PLATE 8

Figs. 1-3. *Septobasidium* sp. Close to *S. Langloisii*.

Fig. 4. *S. Langloisii* Pat. on *Magnolia virginiana* from Florida.  $\times$  about 4.

Figs. 5-7. *S. sinuosum* n. sp. Fig. 5, No. 9240; figs. 6, 7, No. 8475.

PLATE 8



PLATE 8

Figs. 1-3. *Septobasidium* sp. Close to *S. Langloisii*.

Fig. 4. *S. Langloisii* Pat. on *Magnolia virginiana* from Florida.  $\times$  about  $\frac{3}{4}$ .

Figs. 5-7. *S. sinuosum* n. sp. Fig. 5, No. 9240; figs. 6, 7, No. 8475.

PLATE 8



PLATE 9

Figs. 1-4. *S. tenue* n. sp. Black dots are elevated mounds each one covering a scale insect.

Figs. 5, 6. *S. rugulosum* n. sp. Fig. 5  $\times$  about 4. Fig. 6  $\times$  about 2. In both the black dots are depressed areas in each of which is a scale insect. Fig. 6 shows rugulose surface.

PLATE 9

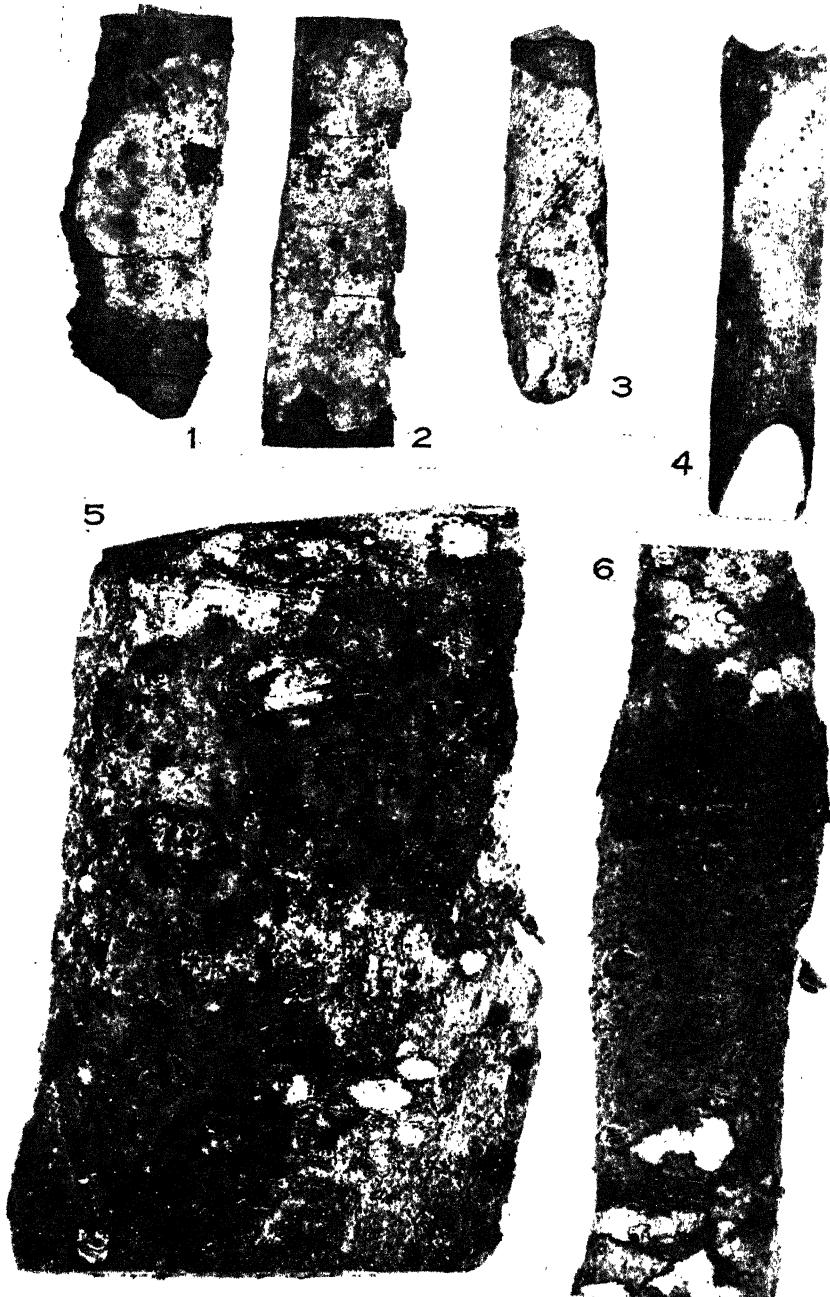


PLATE 10

*S. pseudopedicellatum* Burt

Fig. 1. Fragment of type showing whitish subiculum and dark top layer. Fig. 2. Small patch of growth on *Carpinus*, No. 9389. Figs. 3 and 4. On *Carpinus*, Oct. 23, 1932, No. 9325. Fig. 5. On *Carpinus*, May 14, 1933, No. 8889. Fig. 6. On *Cornus amomum*. Note white subiculum and rich brown shiny top surface. Fig. 7. Typical material on *Citrus* leaf, from Fla. F. A. Wolf, coll. Fig. 8 on *Citrus* twig, from Brazil. Azevedo, coll.

PLATE 10



PLATE 11

*S. pseudopedicellatum* Burt

Figs. 1-3. Showing wood injury. Note *S. Schweinitzii* on lower right side of piece to left.

PLATE 11



PLATE 12

Figs. 1-5. *S. cremeum* n. sp. on *Liquidambar*.  
Figs. 6-10. *S. apiculatum* n. sp.  
Fig. 11. *S. leprosum* n. sp. Slightly reduced.

PLATE 12

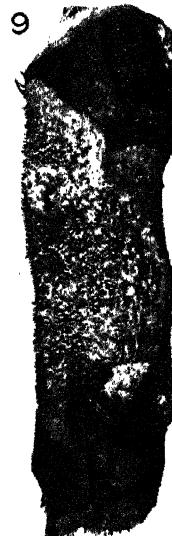


PLATE 13

Figs. 1-4. *S. Hesleri* n. sp.

Figs. 5-10. *Septobasidium* hybrid species between *S. pseudopedicellatum* and *S. Schweinitzii*. Fig. 6 also shows some *S. Patouillardii* Burt.

Figs. 11-13. *S. fuscum* n. sp. Note dark elevated mounds in 12 and 13.

PLATE 13



PLATE 14

Fig. 1. *S. sabalis* n. sp. From Louisiana, Brown, coll. Type.

Fig. 2. *S. sabal-minor* n. sp. From Florida, Bomhardt, coll. Type.

Figs. 3, 4. *S. n.* sp. On pineapple leaf from Canal Zone, Weston, coll. Type  
(to be described later).

PLATE 14

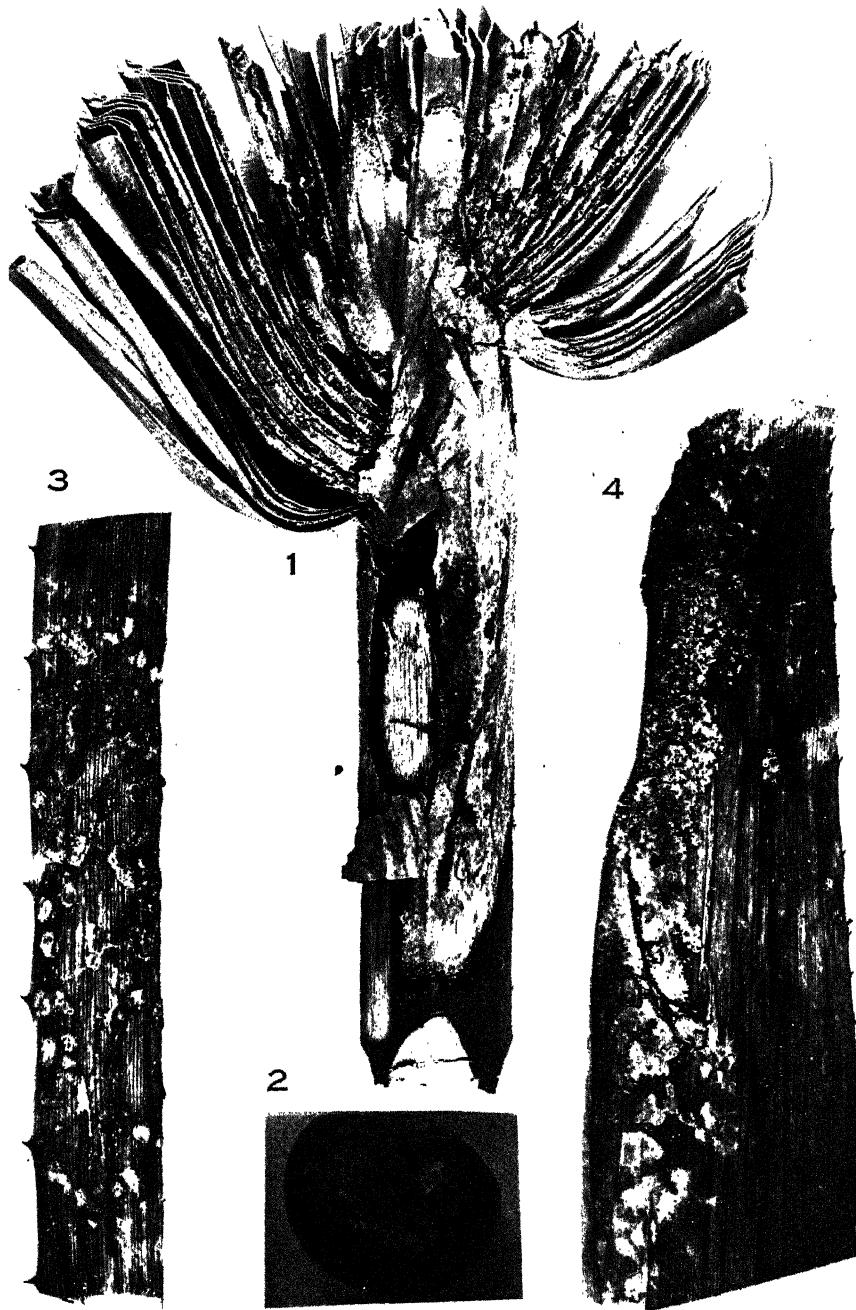


PLATE 15

Figs. 1-6. *S. Schweinitzii* Burt. Fig. 5 (below) *S. Schweinitzii*, (above) *S. pseudopedicellatum*. Fig. 6 shows enlarged ( $\times$  about 5) view of margin with minute tent-like structures.

Figs. 7-11. *S. Patouillardii* Burt.

PLATE 15

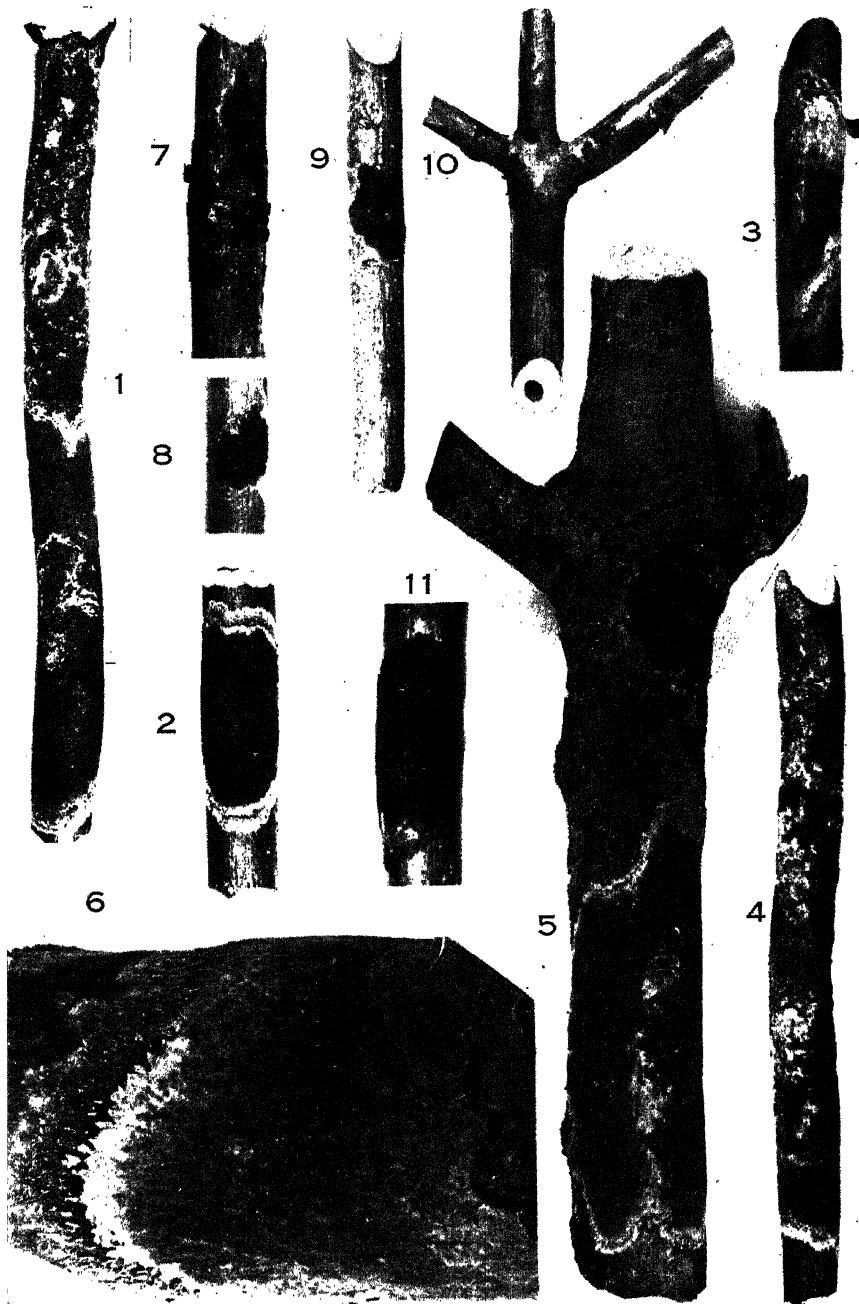


PLATE 16

Figs. 1-8. *S. filiforme* n. sp. Fig. 8 (above) *S. Cokeri*, (below) *S. filiforme*.  
Figs. 9-13. *S. lilacinoalbum* n. sp. Fig. 11 shows margin.  $\times$  about 4.

PLATE 16

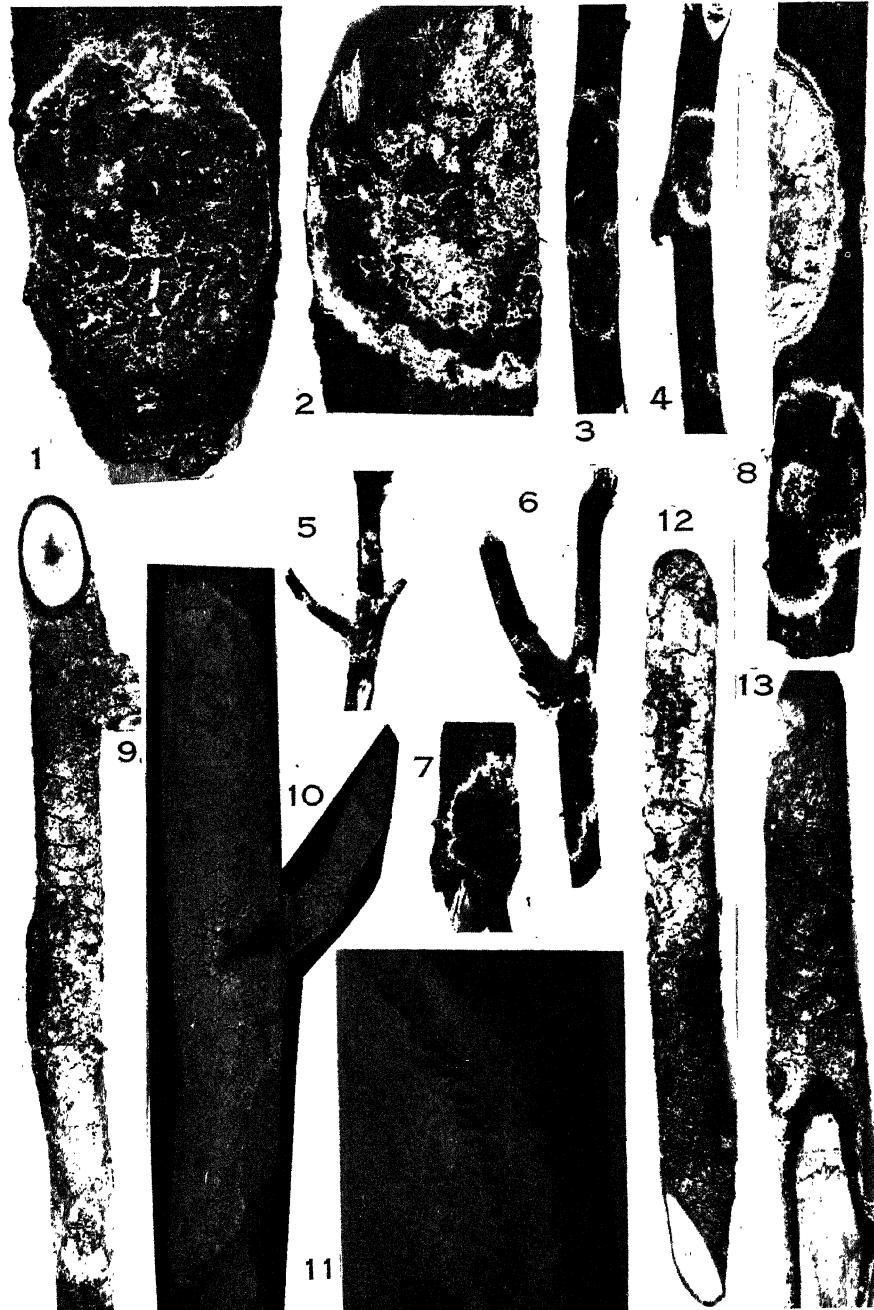


PLATE 17

Figs. 1-2. *S. Peckii* n. sp.  $\times 1.5$ .

Figs. 3-6. *S. Cokeri* n. sp. Fig. 3 shows wood injury on dogwood.

Fig. 5. Section view showing subiculum, pillars, and top layer.

Fig. 6. Surface view of part of same specimen as shown in fig. 5. Figs. 5 and 6  
 $\times$  about 10. Both photographed in fresh condition. Note pure whiteness  
throughout.

PLATE 17



1



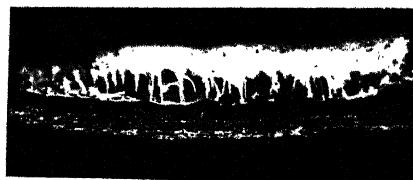
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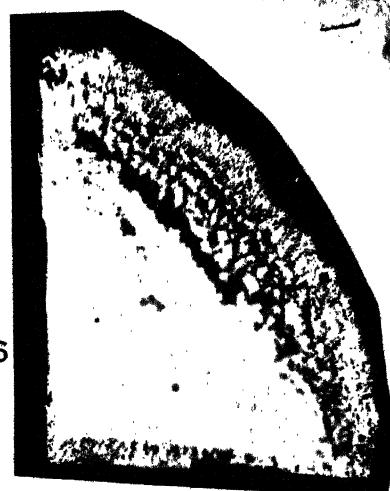
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4



5



6



PLATE 18

Figs. 1-8. *S. pilosum* B. & S.

Fig. 1. Diagram sketch through a tuft of growth, showing upright hyphae bearing conidia, and beneath the fungus in the center a parasitized scale insect. Note the coiled threads connecting insect with hyphal pad.  $\times 18$ .

Fig. 2. Several upright hyphae bearing conidia.  $\times 110$ .

Figs. 3 and 4. Conidia.  $\times 525$ .

Fig. 5. Thick-walled hyphae found in basal region.  $\times 525$ .

Fig. 6. Haustoria from parasitized insect.  $\times 525$ .

Fig. 7. Probasidia of type.  $\times 525$ .

Fig. 8. Showing connection between haustoria and external thread.  $\times 525$ .

Figs. 9-13. *S. pinicola* Snell.

Fig. 9. Sketch of section of *S. pinicola*, showing very irregular surface, parasitized and healthy insects.  $\times 18$ .

Figs. 10 and 11. Basidia and spores.  $\times 525$  and  $\times 580$ , respectively.

Figs. 12 and 13. Haustoria of "glomerulus" type.  $\times 580$ .

Figs. 14-17. *S. Hesleri* n. sp.

Fig. 14. Sketch of margin showing a few scattered pillars arising from subiculum, several "insect houses" from one of which roof has been lifted, exposing insect.  $\times 18$ .

Fig. 15. Hymenial section showing dichotomously branched paraphyses, coiled basidia, and spore.  $\times 580$ .

Fig. 16. Spores, one of which has become septate, each septum forming a sterigma.  $\times 580$ .

Fig. 17. Crystal-encrusted, upright threads from subiculum.  $\times 335$ .

PLATE 18

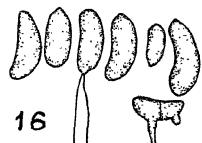
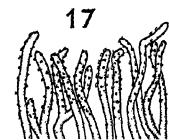
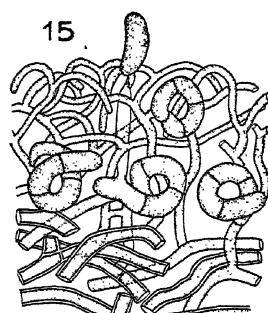
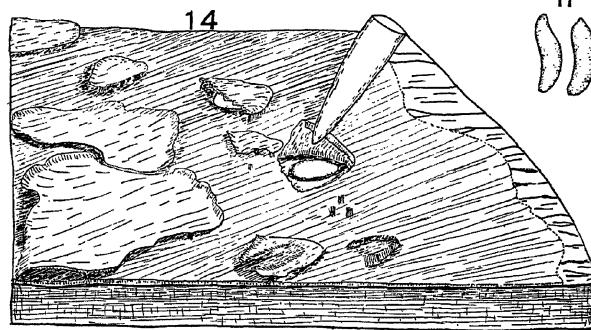
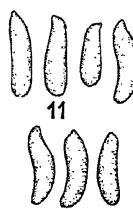
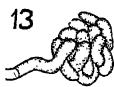
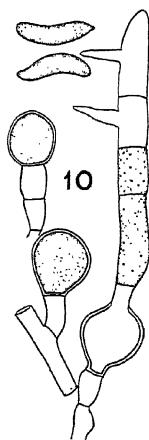
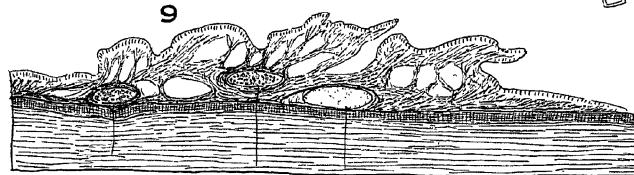
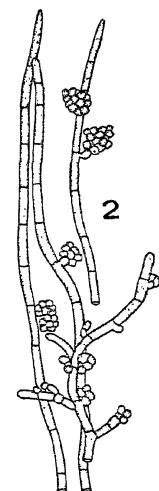
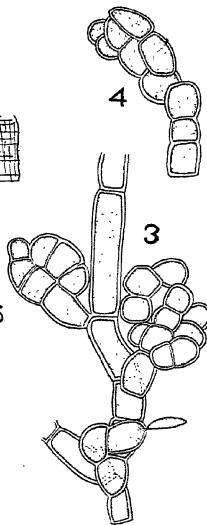
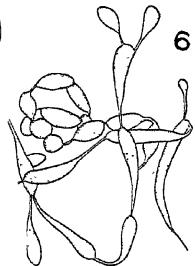
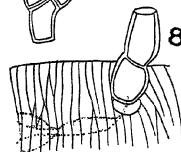
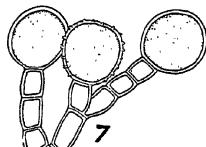
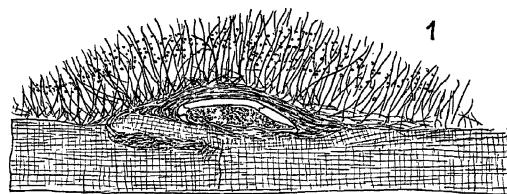


PLATE 19

*S. lepidosaphis* n. sp.

Fig. 1. Sketch of marginal region, showing subiculum which in this species bears probasidia, basidia, and spores. Note anastomosing and branching pillars, top layer, and part of a scale insect.  $\times 23$ .

Fig. 2. Spores.  $\times 833$ .

Fig. 3. Large cells filled with protoplasm in subiculum.  $\times 833$ .

Fig. 4. Surface view of subiculum showing hyphae, probasidia, basidia and spores on epidermis of leaf.  $\times 833$ .

Fig. 5. Irregularly coiled haustoria.  $\times 833$ .

Fig. 6. Adult healthy scale insect, *Lepidosaphes beckii*.  $\times 100$ .

PLATE 19

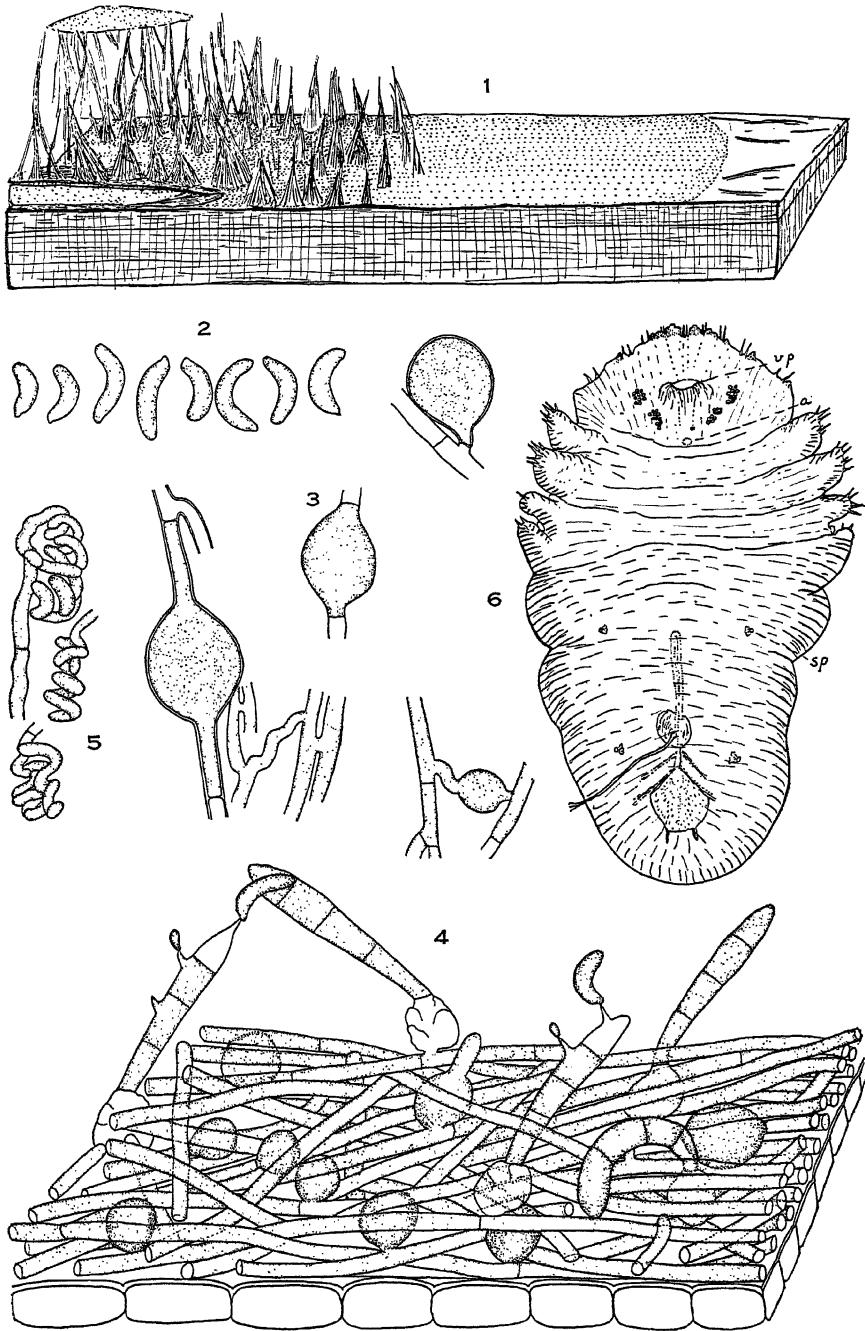


PLATE 20

*S. Carestianum* Bres.

Fig. 1. Sketch showing section of hymenium, pillars, parasitized insect, and wood.  $\times 33$ .

Figs. 2-7. Probasidia. Figure 5 also shows a thread from hymenial region.  $\times 833$ .

Figs. 8 and 9. Basidia.  $\times 833$ .

Fig. 10. Enlarged club-shaped bodies found in hymenial region in fall and winter.  $\times 833$ .

Fig. 11. *Chionaspis corni* associated with *S. Carestianum*. This female was giving birth to young when collected.  $\times 60$ .

Fig. 12. Section of hymenial region of young fertile plant in late spring.  $\times 833$ .

Fig. 13. Empty probasidia showing club-shaped bodies growing through two probasidial cells.  $\times 833$ .

Fig. 14. Haustoria.  $\times 833$ .

PLATE 20

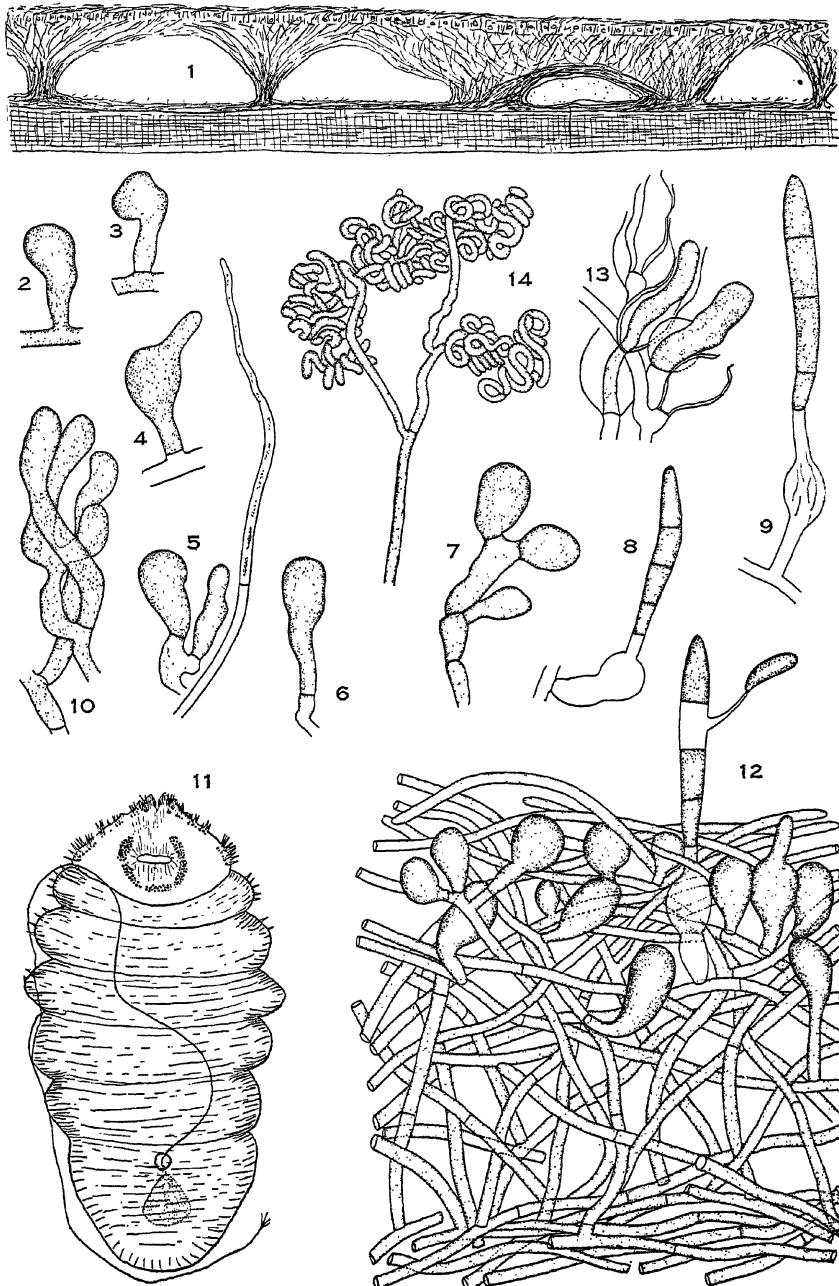


PLATE 21

*S. alni* Torrend

Fig. 1. Section showing top layer with hymenium, pillars, one parasitized scale insect, and subiculum. No. 8325.  $\times 33$ .

Fig. 2. Section of hymenium showing probasidia, basidia, and spores. No. 8326.  $\times 833$ .

Fig. 3. Spores. No. 8326.  $\times 833$ .

Figs. 4-7. Empty probasidia, showing proliferation. Torrend, coll. In New York Bot. Gard. Herb. No. 373.  $\times 833$ .

Figs. 8-10. Empty and proliferating probasidia. Type from Sydow, No. 68.  $\times 833$ .

Figs. 11 and 12. Empty probasidia. From Georgia, Higgins, coll., No. 8498.  $\times 733$ .

Fig. 13. Proliferating probasidium (?). N. Y. Bot. Gard. Herb. No. 373.  $\times 833$ .

Fig. 14. Haustoria.  $\times 833$ .

PLATE 21

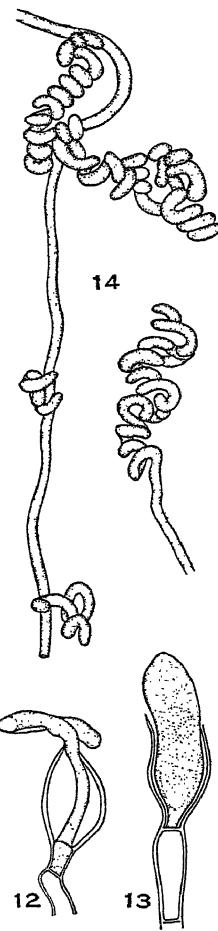
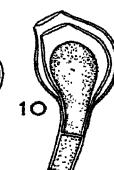
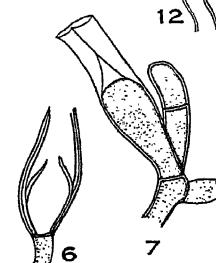
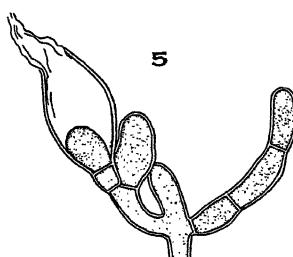
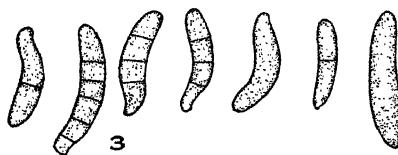
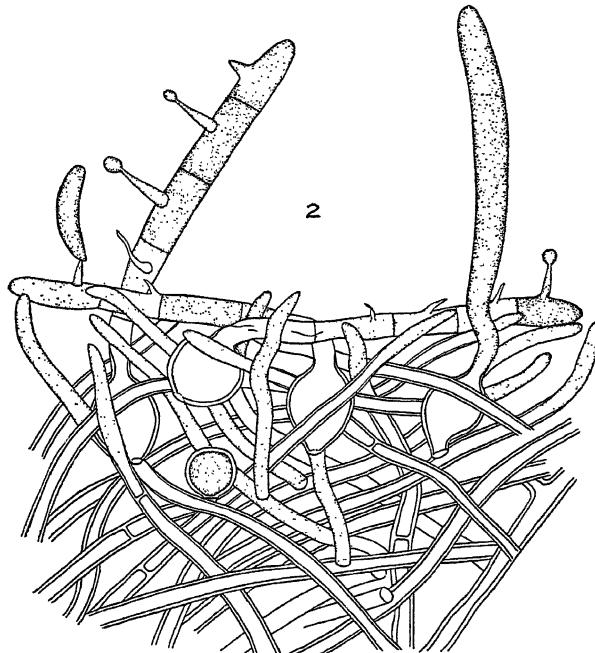
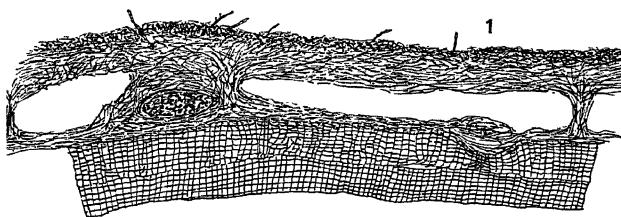


PLATE 22

*S. sabal-minor* n. sp.

Fig. 1. Sketch through outer part of fruit of *Sabal minor* showing fungus covering scale insect.  $\times 38$ .

Fig. 2. Hymenium showing probasidia and basidia.  $\times 938$ .

Figs. 3-7. Probasidia and basidia.  $\times 938$ .

Fig. 8. Spores.  $\times 938$ .

Fig. 9. Haustorium.  $\times 938$ .

PLATE 22

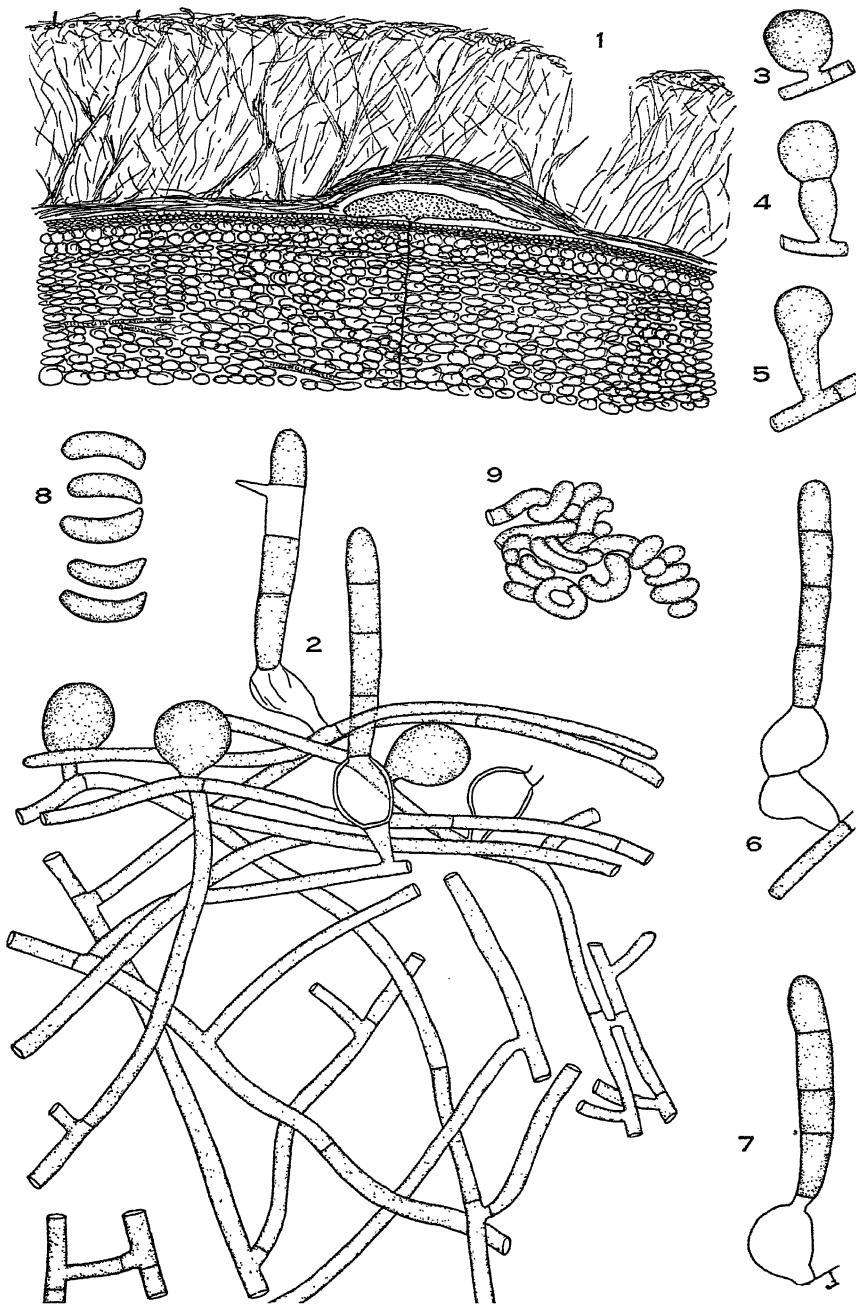


PLATE 23

*S. sumigatum* Burt.

Fig. 1. Section showing hymenium, context, and subiculum, also a scale insect.  
X 33. Fig. 2. Hymenium, with coiled paraphyses, probasidia, basidia,  
and spores. No. 8458. X 833.

Fig. 3. Three basidia of type material. X 833.

Fig. 4. Basidium of material from Alabama. Mo. Bot. Garden Herb. No. 20068.  
X 833.

Fig. 5. Haustoria within *Aspidiota tenebricosus* on *Cornus florida* from Florida.  
X 833.

PLATE 23

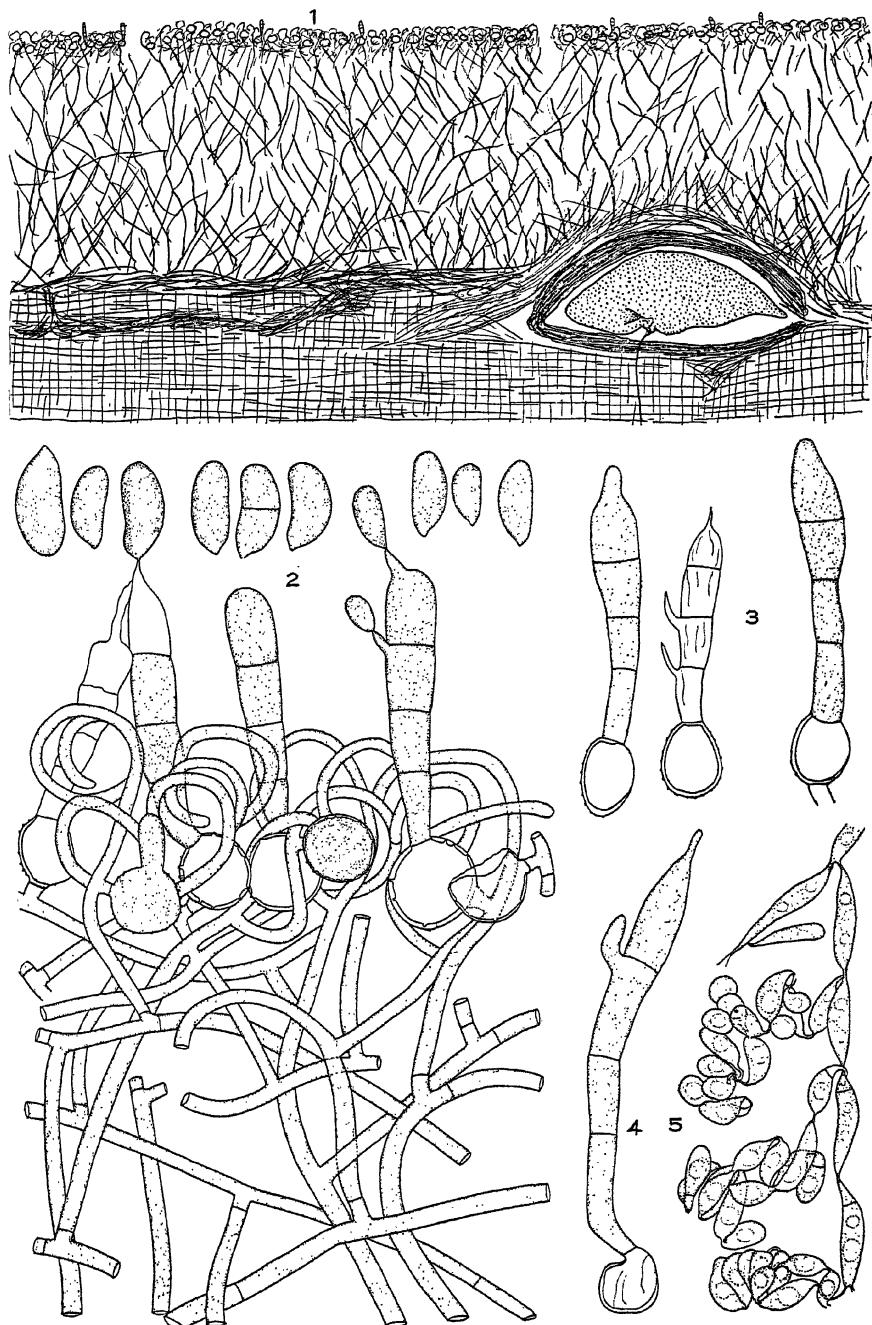


PLATE 24

*S. fuscum* n. sp.

Fig. 1. Section showing fertile region and thick tufts of upright hyphae over insects.  $\times 33$ .

Fig. 2. Enlarged section showing subiculum and hymenium with recurved paraphyses, probasidia, basidia, and spores.  $\times 833$ .

Fig. 3. Spores.  $\times 833$ .

Fig. 4. Haustoria.  $\times 833$ .

Fig. 5. View of parasitized insect in spiracular region showing a fungal coil surrounded by chitinous material. A connection is shown between coil and external hyphae passing through dermal pore.  $\times 833$ .

Fig. 6. Showing how fungal pad may overgrow part of insect.  $\times 833$ .

PLATE 24

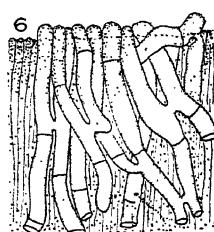
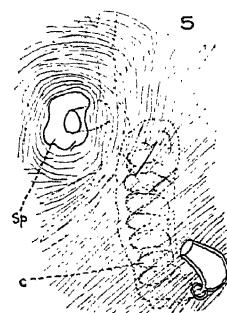
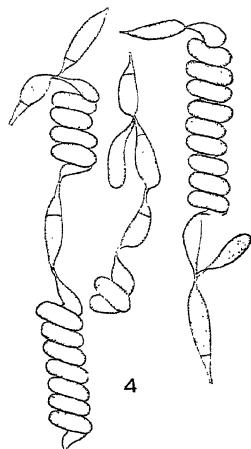
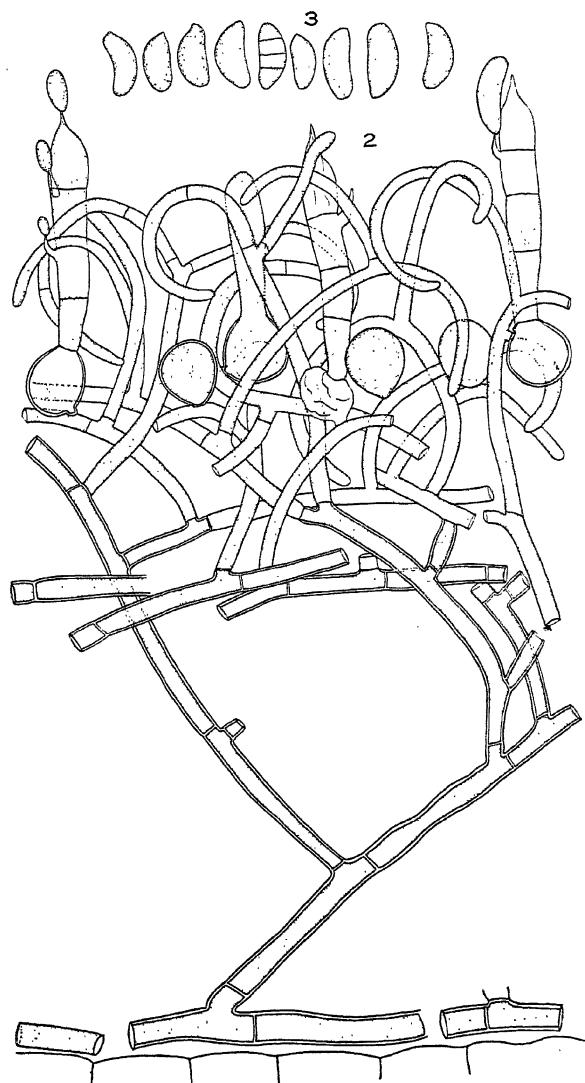
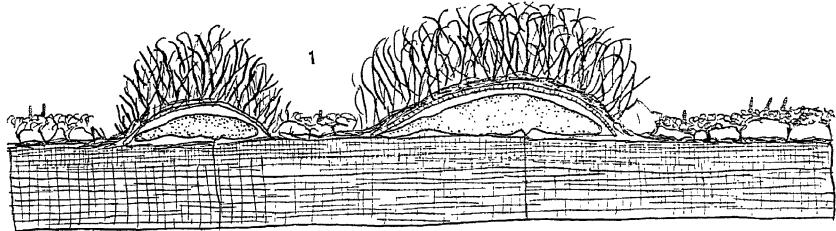


PLATE 25

Figs. 1-3. *S. castaneum* Burt.

Fig. 1. Sketch of type showing very irregular marginal condition. Stubby pillars and three horizontal layers are shown in places, also note scale insects.  $\times 9$ .

Fig. 2. Hymenial region showing probasidia and basidia.  $\times 833$ .

Fig. 3. Spores.  $\times 833$ .

Fig. 4. *S. alni* var. *squamosum* n. var. Sketch showing surface and sectional view.  $\times 18$ .

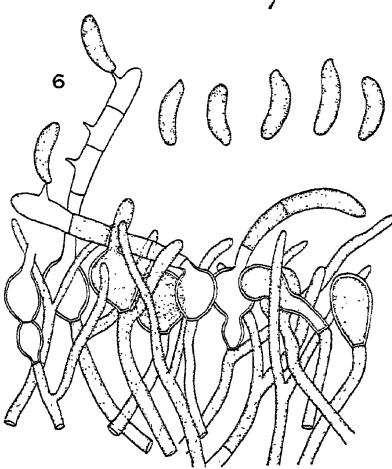
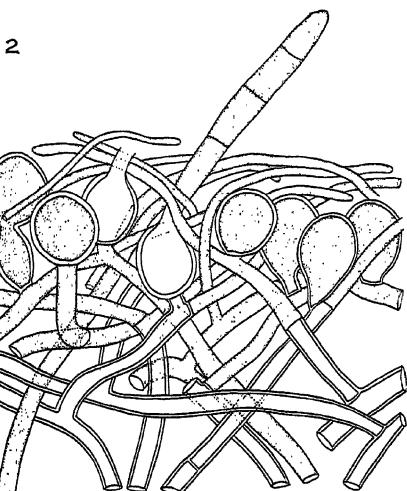
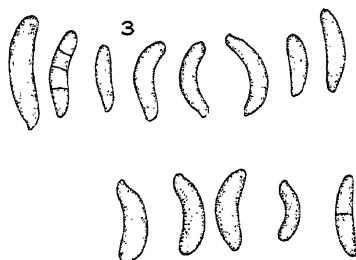
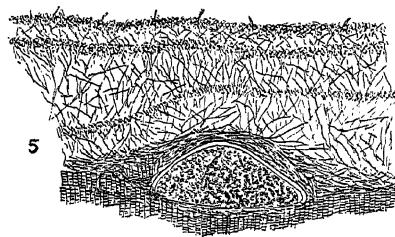
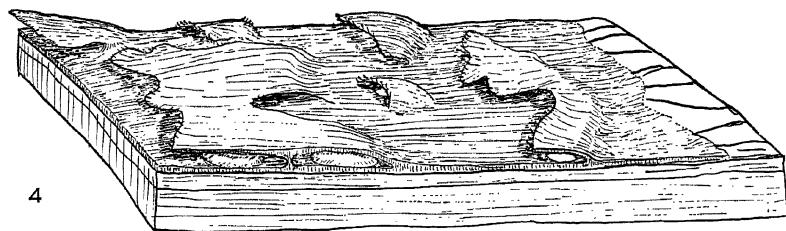
Figs. 5-7. *S. Leprieurii* (Mont.) Pat.

Fig. 5. Section showing stratification of fungus, the top stratum being fertile with mature basidia. Note parasitized scale insect.  $\times 33$ .

Fig. 6. Section of hymenium showing probasidia, basidia, and spores.  $\times 833$ .

Fig. 7. Spores.  $\times 833$ .

PLATE 25



7

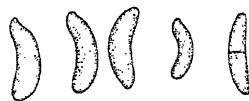


PLATE 26

*S. Mariani* Bres.

Fig. 1. Section showing three vertical layers of fungus, the hymenial surface showing probasidia and basidia. Note branched and anastomosing pillars also parasitized scale insect beneath fungus.  $\times 33$ .

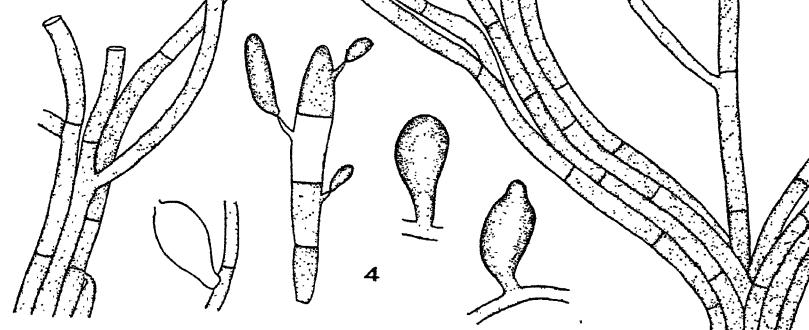
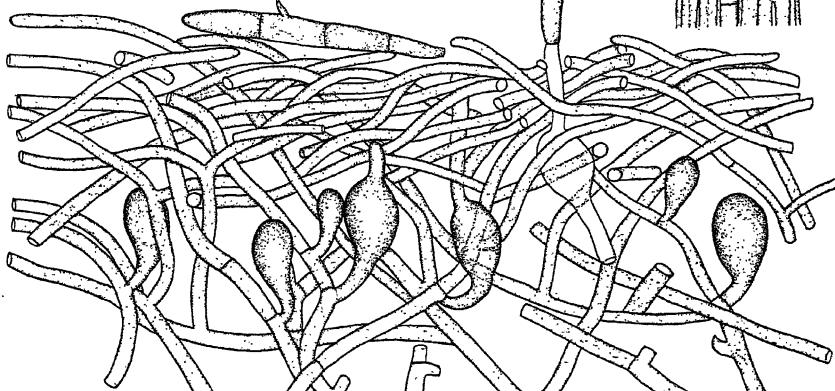
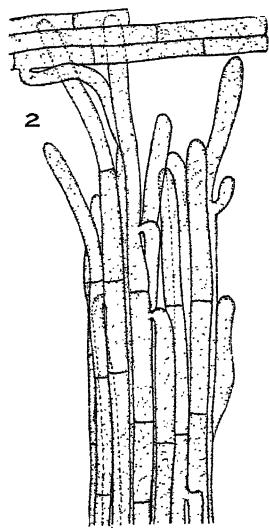
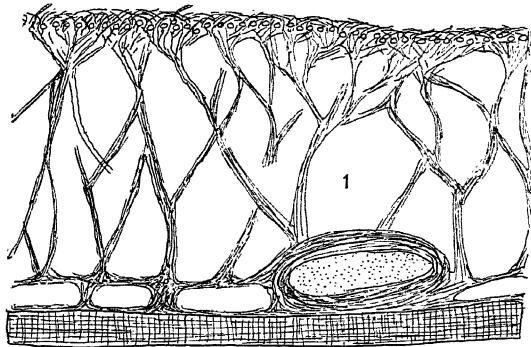
Fig. 2. Anastomosing pillars.  $\times 833$ .

Fig. 3. Section through hymenial region showing probasidia and basidia.  $\times 833$ .

Fig. 4. Probasidia and basidium.  $\times 833$ .

Fig. 5. Spores.  $\times 833$ .

PLATE 26



5

4

PLATE 27

*S. pseudopedicellatum* Burt.

Fig. 1. Sketch showing subiculum, pillars, and top layer. Note tuft of short threads at base of pillars.  $\times 18$ .

Fig. 2. Section through hymenium showing probasidia, basidia, spores, and paraphyses. At left are two probasidial cells each of which has formed one basidium and into which new probasidia have proliferated. Type.  $\times 700$ .

Fig. 3. Spores. Above on *Carpinus*, No. 9389, from North Carolina; below on *Citrus* from Brazil, Müller, coll., No. 9722.  $\times 700$ .

Fig. 4. Spores. On *Fraxinus*. No. 8401.  $\times 833$ .

Figs. 5 and 6. Various shapes and sizes of basidia.  $\times 833$ .

PLATE 27

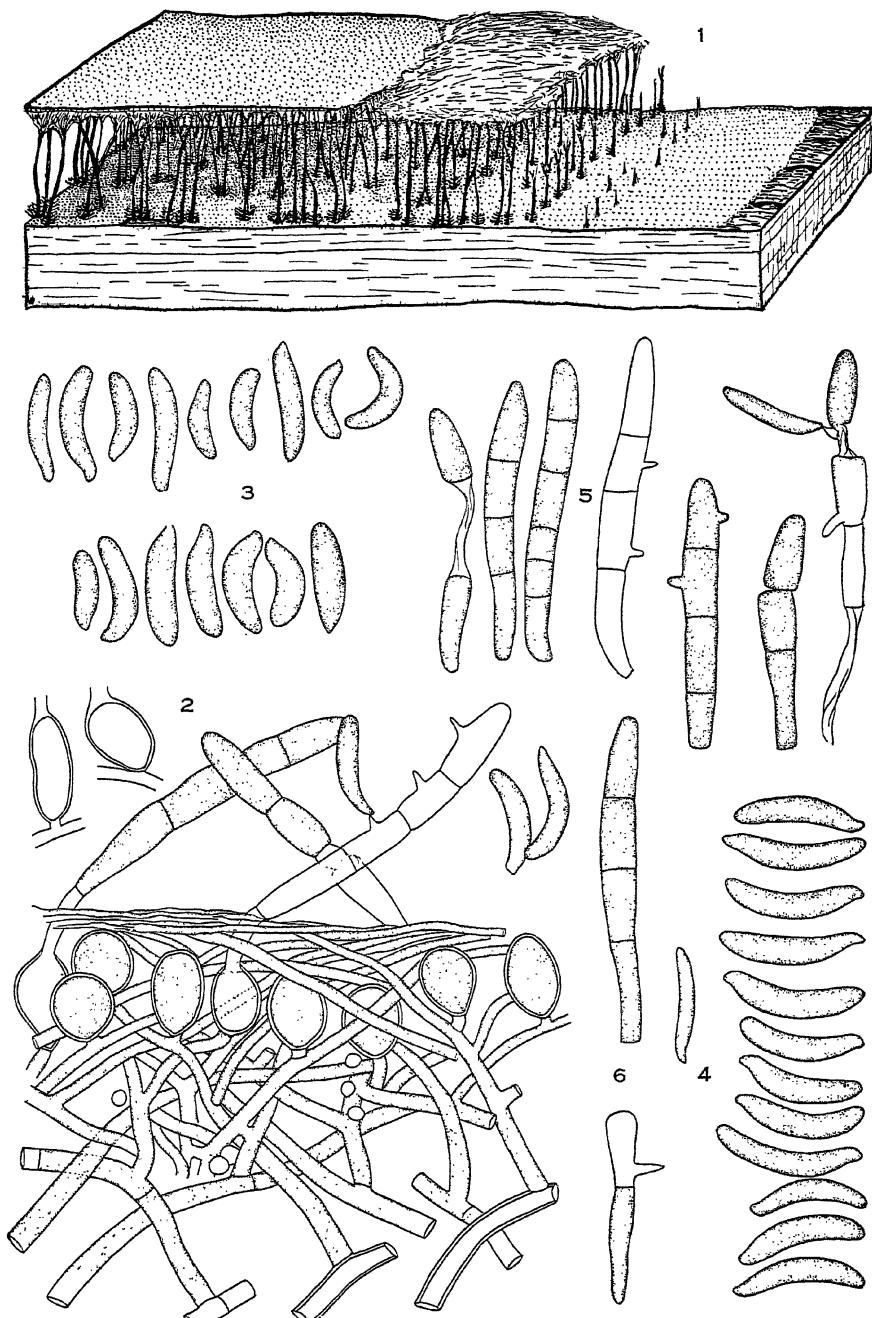


PLATE 28

*S. Burtii* Lloyd

(= *S. retiforme* sense of American authors but not Patouillard.)

Fig. 1. Section of hymenium showing probasidia, basidia, and spores.  $\times 938.$

Fig. 2. Spores showing two types of budding. The four to left show close type of budding, the other four show open type of budding.  $\times 938.$

Fig. 3. Hyphae and bud cells on agar.  $\times 938.$

Fig. 4. Germination on agar of coiled haustoria.  $\times 825.$

PLATE 28

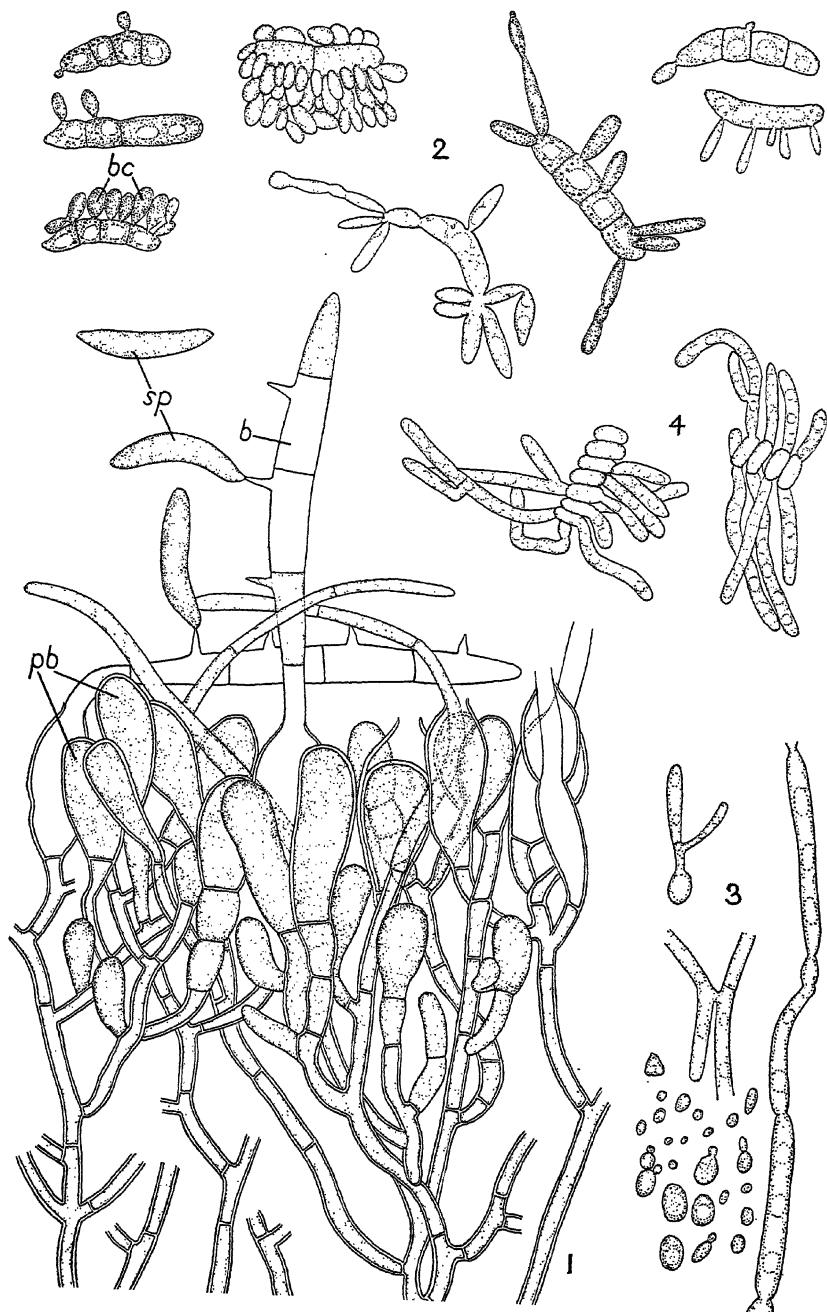


PLATE 29

Figs. 1-3. *S. sinuosum* n. sp.

Fig. 1. Hymenium showing probasidia, basidia, spores, and paraphyses.  
X 833.

Fig. 2. Basidia of Mo. Bot. Gard. Herb. No. 44211. X 833.

Fig. 3. Segments of haustoria from parasitized insects. X 833.

Figs. 4 and 5. *S. leprosum*.

Fig. 4. Section through hymenium, context, and subiculum showing probasidia,  
basidia, and spores. X 533.

Fig. 5. Spores. X 833.

PLATE 29

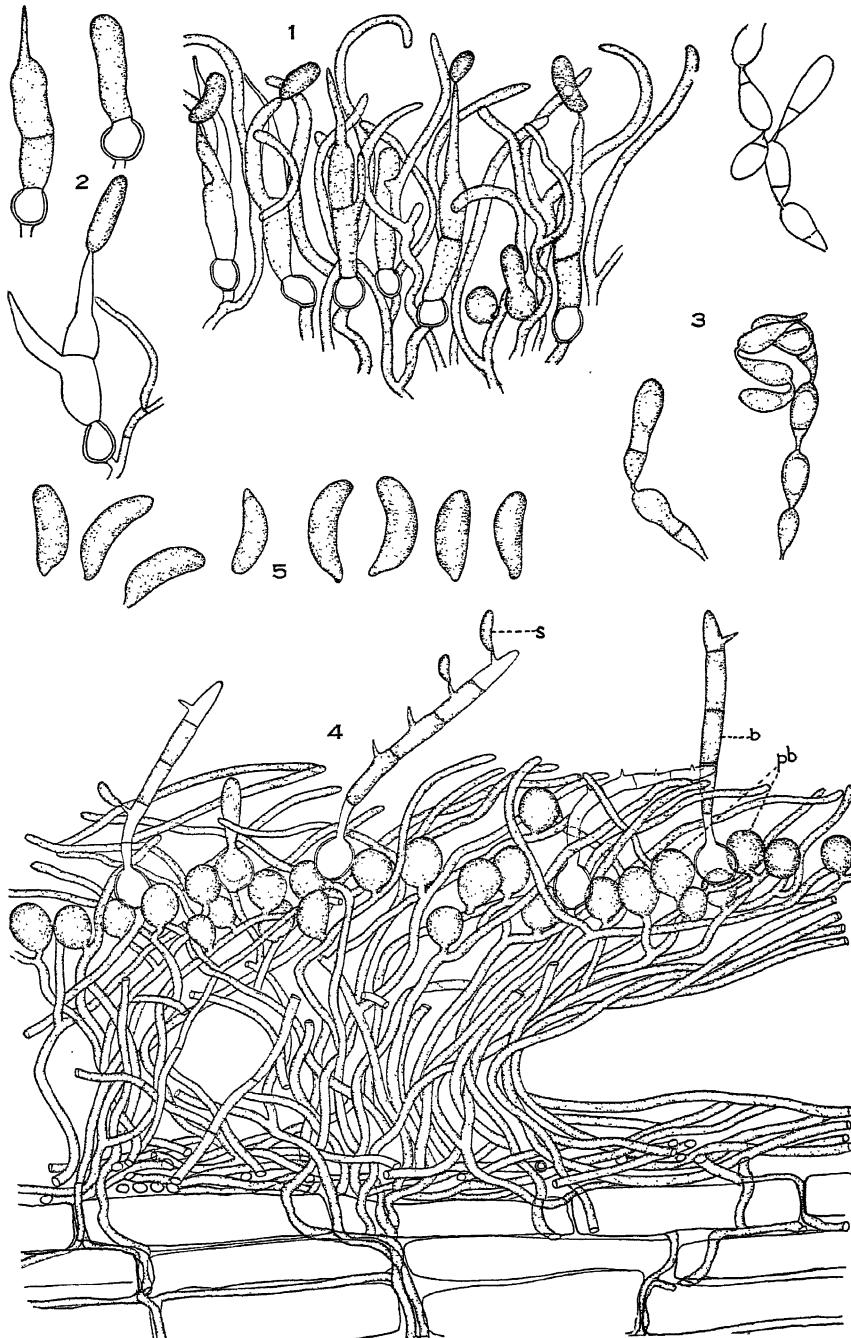


PLATE 30

*S. Sydowii* n. sp.

Fig. 1. Section through fungus showing compact context and stratified hymenium.  $\times 33$ .

Fig. 2. Section of hymenium showing probasidia, coiled basidia and spores.  
Also note old collapsed probasidial cells at base of hymenium.  $\times 833$ .

Figs. 3-5. Basidia.  $\times 833$ .

Fig. 6. Spores.  $\times 833$ .

Fig. 7. Haustoria.  $\times 833$ .

Fig. 8. Anal segment of scale insect associated with *S. Sydowii*.  $\times 233$ .

PLATE 30

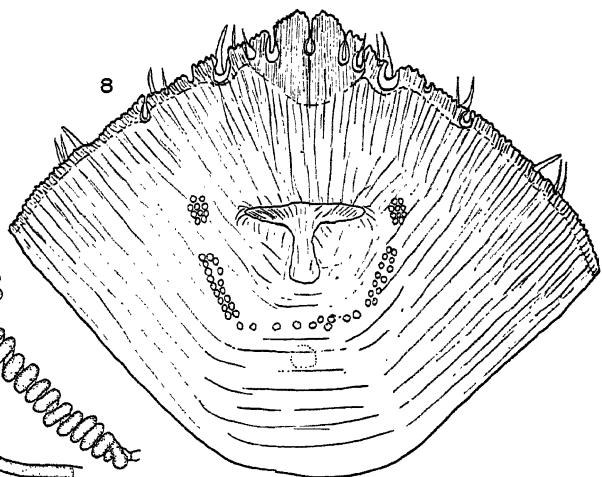
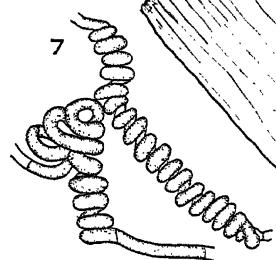
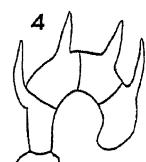
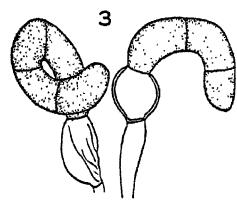
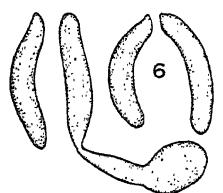
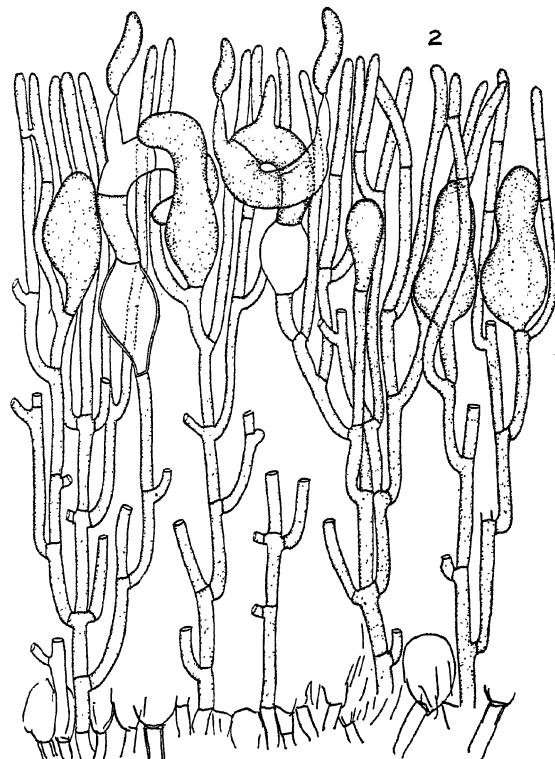
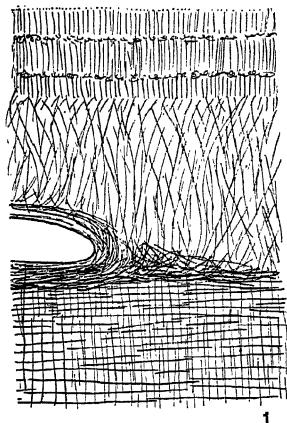


PLATE 31

*S. cremeum* n. sp.

Fig. 1. Section through marginal region of fungus showing hymenium with basidia, pillars, subiculum and one scale insect.  $\times 33$ .

Fig. 2. Hymenial region, showing empty probasidia, basidia, spores, and paraphyses.

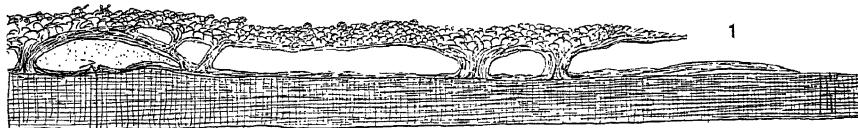
Fig. 3. Spores.  $\times 833$ .

Fig. 4. Haustorium from parasitized insect.  $\times 833$ .

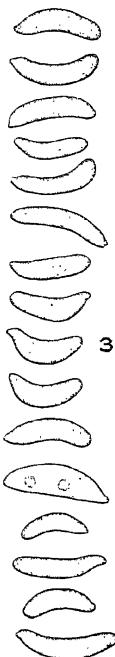
Fig. 5. *Aspidiotus liquidambaris* Kot.  $\times 60$ .

Fig. 6. Anal segment of same scale insect, ventral surface.  $\times 233$ .

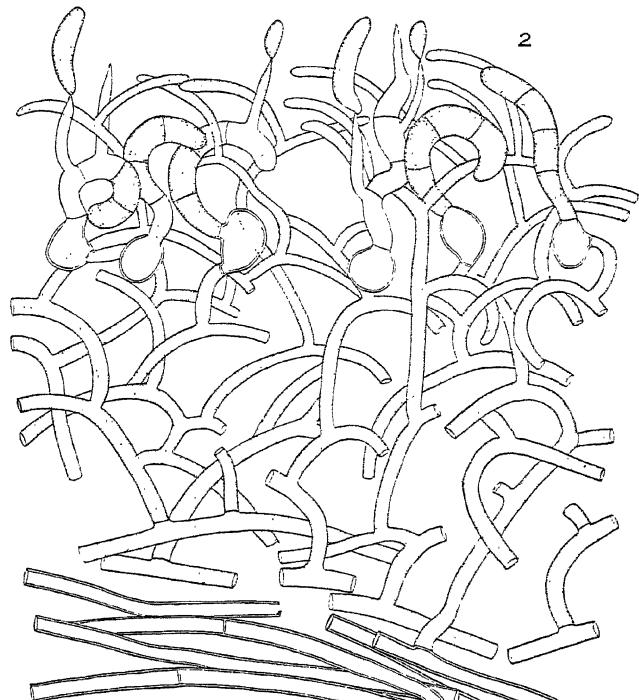
PLATE 31



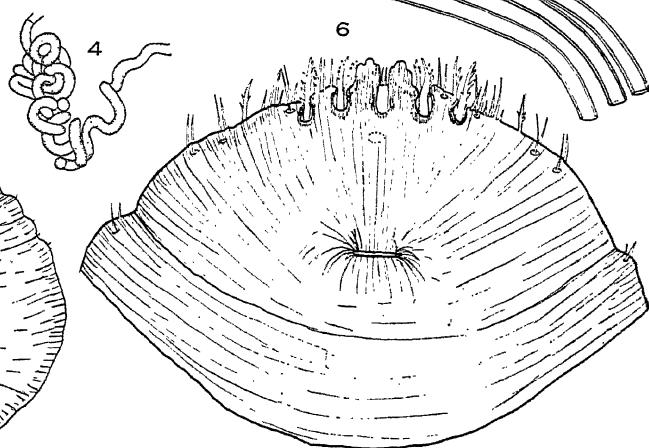
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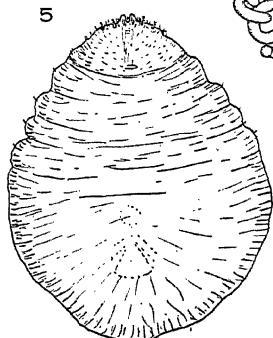
3



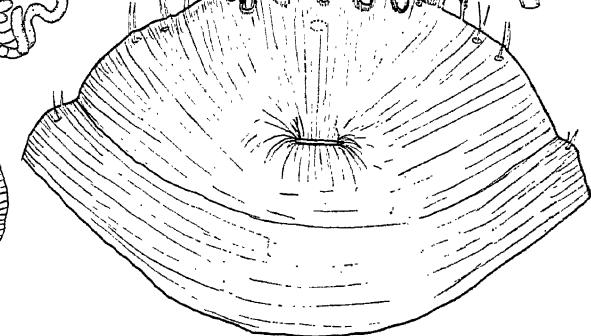
2



6



5



4

PLATE 32

*S. filiforme* n. sp.

Fig. 1. Section of fungus showing hymenium, pillars, subiculum, and three insects.  $\times 33$ .

Fig. 2. Hymenium with probasidia, basidia, and very narrow threads which frequently break up into short bacilliform segments.  $\times 847$ .

Fig. 3. Young basidia.

Fig. 4. Mature basidia and spores.  $\times 833$ .

Fig. 5. Haustoria.  $\times 833$ .

PLATE 32

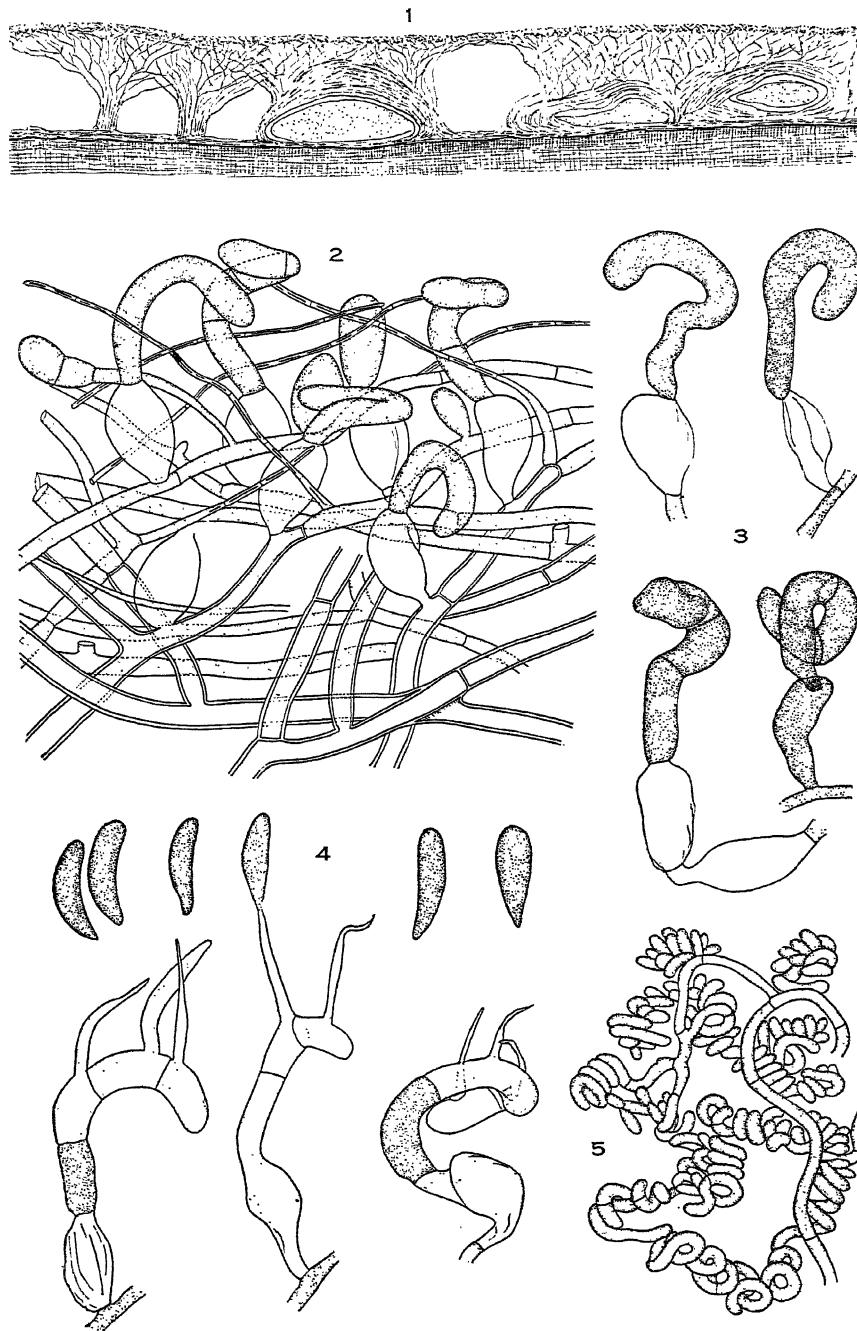


PLATE 33

*S. Schweinitzii* Burt.

Fig. 1. Section of fungus showing hymenium, pillars, subiculum and parasitized insects. No. 5876.  $\times 33$ .

Figs. 2 and 3. Basidia bearing spores.  $\times 847$ .

Figs. 4-8. Probasidia (?) and resting basidia. Type material.  $\times 833$ .

Fig. 9. Hymenium showing upright thick-walled paraphyses, basidia and spores. Coll. March 14, 1929. No. 8397.

Fig. 10. Hymenium showing resting, coiled, septate basidia (?). Coll. Dec. 28, 1921.  $\times 833$ .

Fig. 11. Spores.  $\times 833$ .

PLATE 33

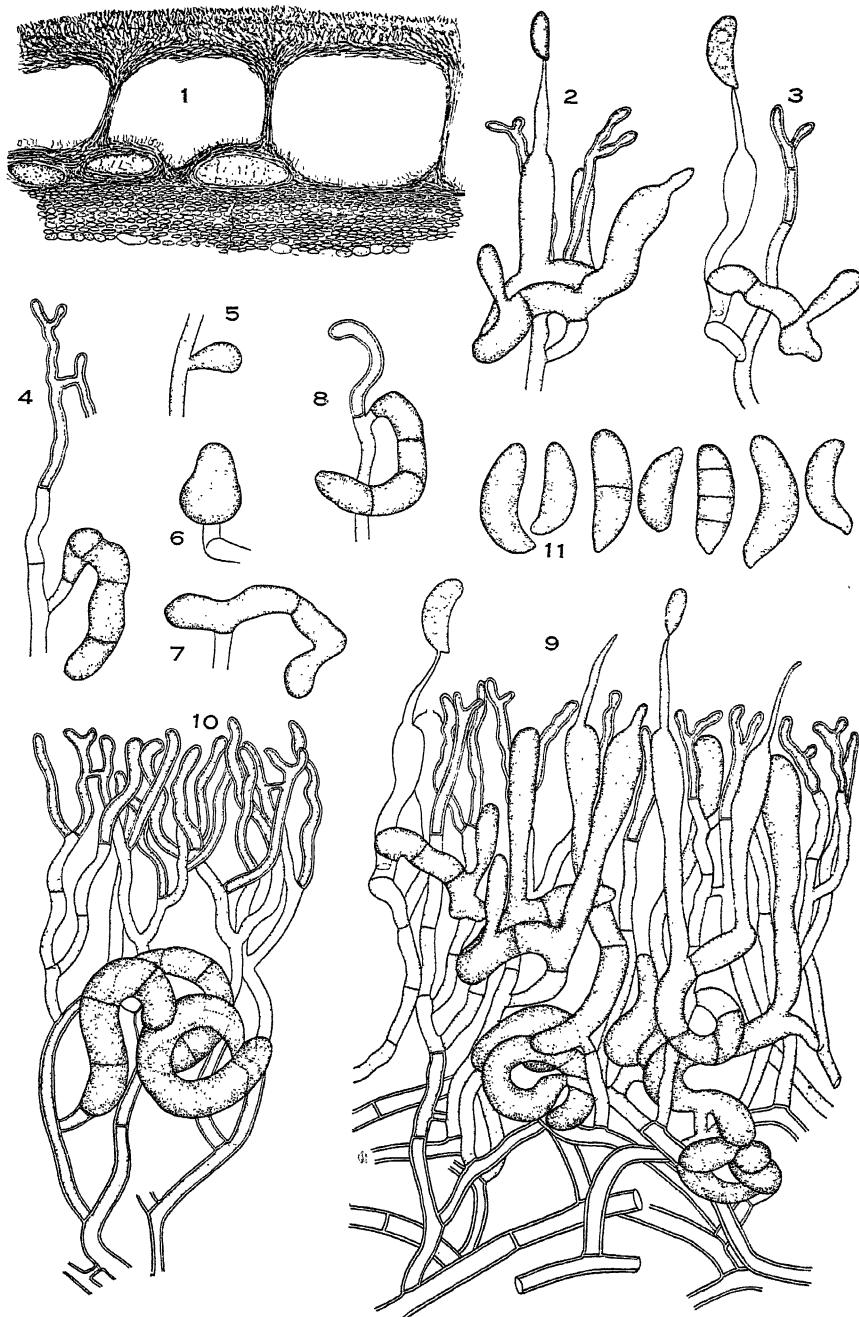


PLATE 34

*S. lilacinoalbum* n. sp.

Fig. 1. Section of fungus showing hymenium, pillars, subiculum and two scale insects.  $\times 33$ .

Fig. 2. Hymenium with basidia, spores, and paraphyses. Note numerous anastomoses between paraphyses.  $\times 833$ .

Fig. 3. Probasidia (?) and basidia.  $\times 833$ .

Fig. 4. Spores.  $\times 833$ .

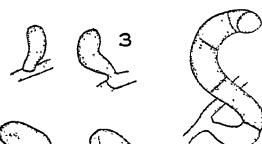
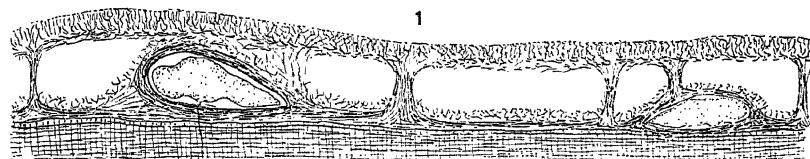
Fig. 5. Paraphyses.  $\times 833$ .

Fig. 6. Segment of hypha showing protoplasmic connection between cells.  $\times 833$ .

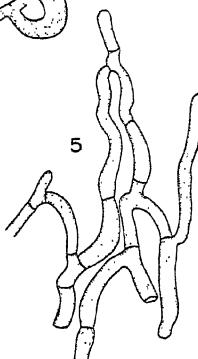
Fig. 7. Haustoria.  $\times 833$ .

Figs. 8 and 9. *Chionaspis gleditsiae* Sanders (?), the scale associated with this fungus. Fig. 8  $\times 60$ ; fig. 9  $\times 233$ .

PLATE 34

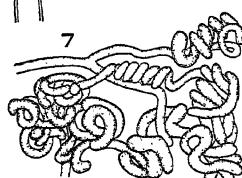
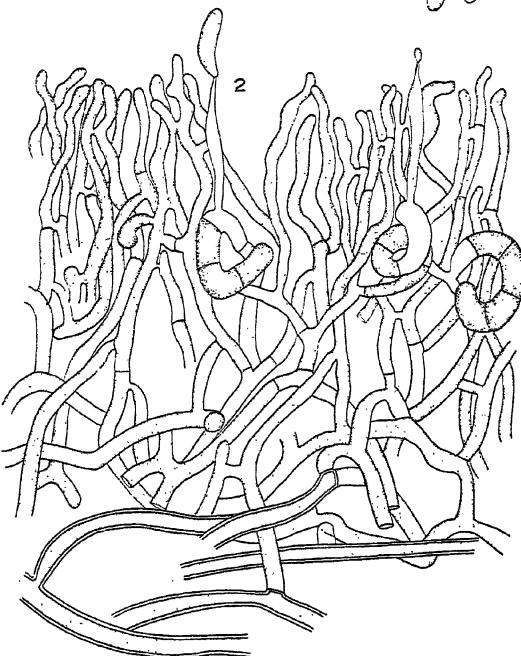


6

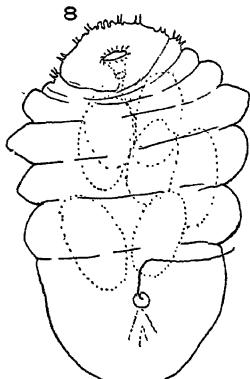


7

2



8



9

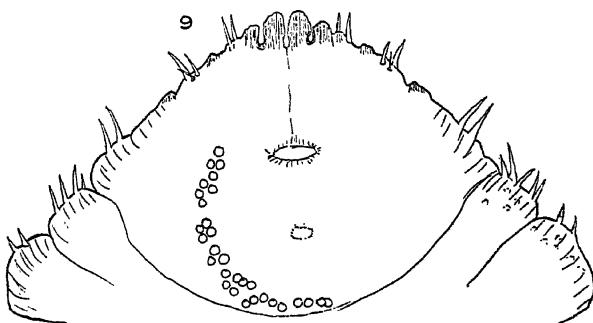


PLATE 35

Hybrid between *S. pseudopedicellatum* Burt and *S. Schweinitzii* Burt.

Fig. 1. Sketch of marginal region of hybrid showing "tents," which are characteristic of *S. Schweinitzii* Burt and "pillars" characteristic of *S. pseudopedicellatum* Burt.  $\times 16$ .

Fig. 2. Hymenium of *S. pseudopedicellatum* Burt showing typical probasidia, basidia and paraphyses.  $\times 750$ .

Fig. 3. Hymenium of hybrid, showing paraphyses characteristic of *S. Schweinitzii* and probasidia and basidia combining characters of both parents.  $\times 696$ .

Figs. 4-10. Stages in development of basidia of hybrid.  $\times 750$ .

PLATE 35

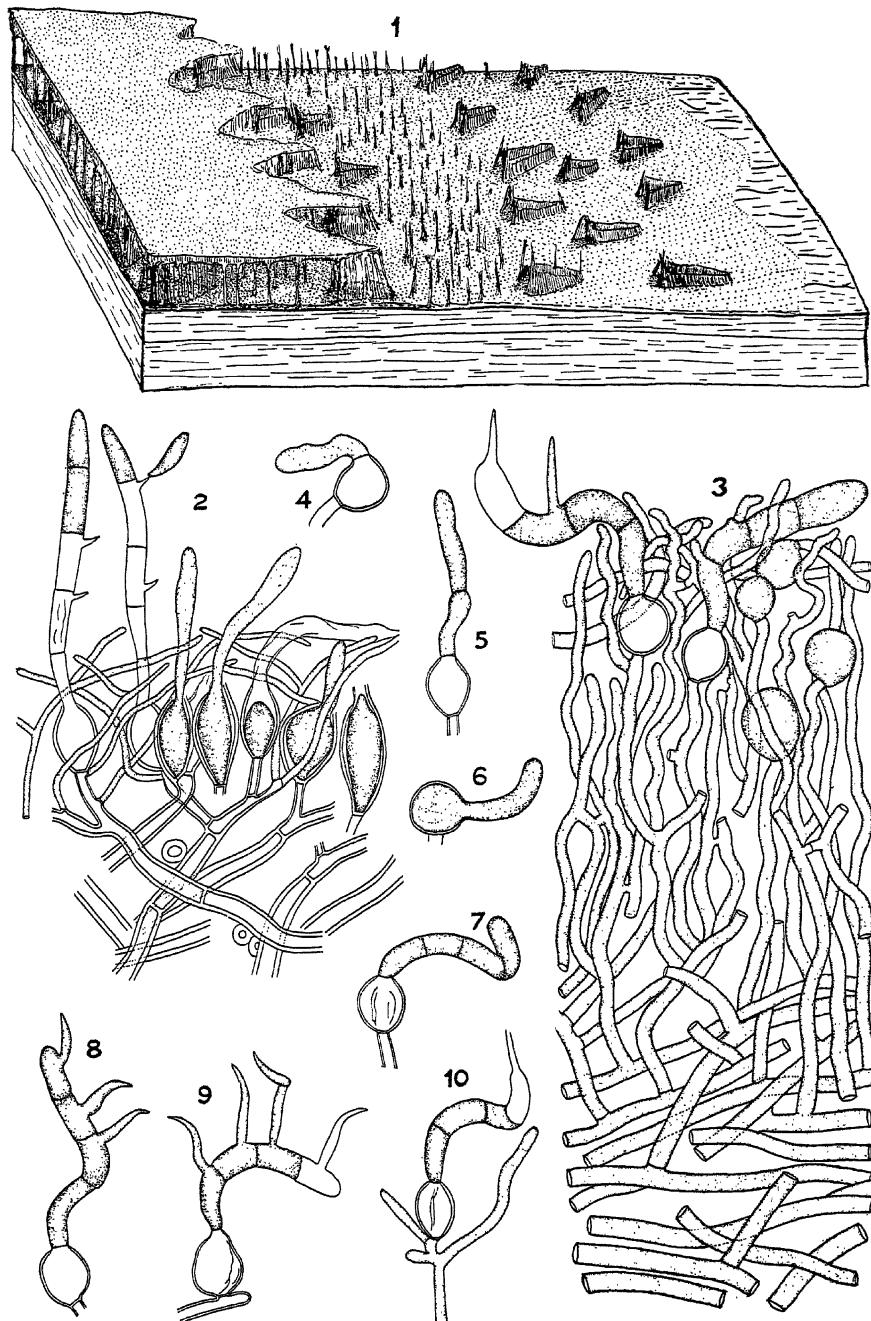


PLATE 36

*S. rugulosum* n. sp.

Fig. 1. Section of fungus, marginal region.  $\times 50$ .

Fig. 2. Section showing context and hymenial region with recurved, crystal encrusted paraphyses and basidia. No. 9251.  $\times 938$ .

Fig. 3. Spores. No. 8472.  $\times 938$ .

Figs. 4-10. Basidia, all of No. 8472 except fig. 9 (No. 9151).  $\times 938$ .

Fig. 11. Hyphal segments of context separated by crushing under a cover slip.  $\times 938$ .

Fig. 12. Associated scale insect, *Chionaspis gleditsiae* (?). From No. 9229.  $\times 68$ .

PLATE 36

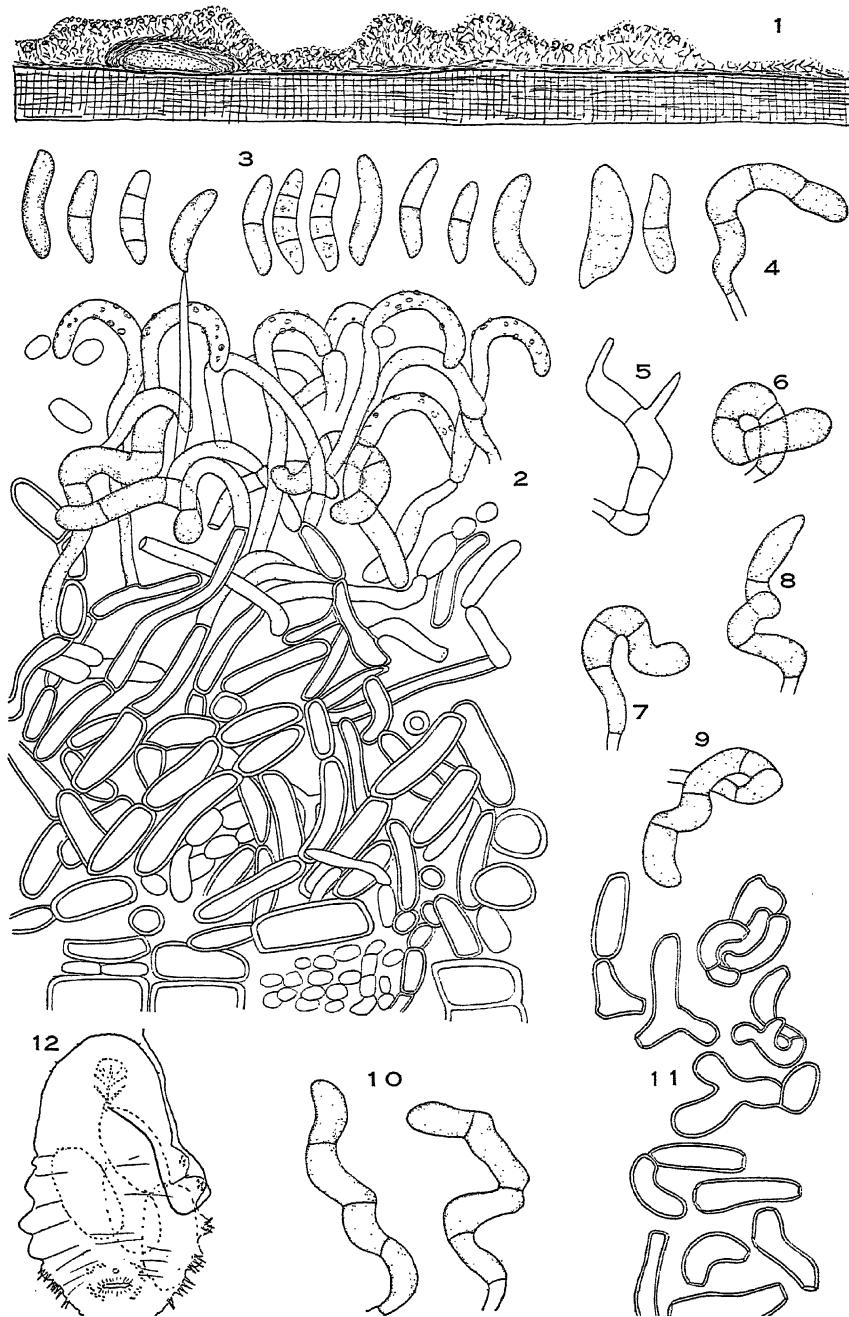


PLATE 37

*S. tenuc* n. sp.

Figs. 1 and 2. Sections of fungus. Fig. 1, No. 9154; fig. 2, No. 9183.  $\times 33$ .

Fig. 3. Section of context and hymenial region showing basidia and spores, paraphyses with crystal encrusted tips. Note algal cells. Also note that hyphae of context are not broken up into short segments.  $\times 833$ .

Fig. 4. Spores, below of No. 8456, above of No. 9154.  $\times 833$ .

Figs. 5-9. Basidia.  $\times 833$ .

Fig. 10. Haustoria from parasitized scale insect. No. 8456.  $\times 833$ .

PLATE 37

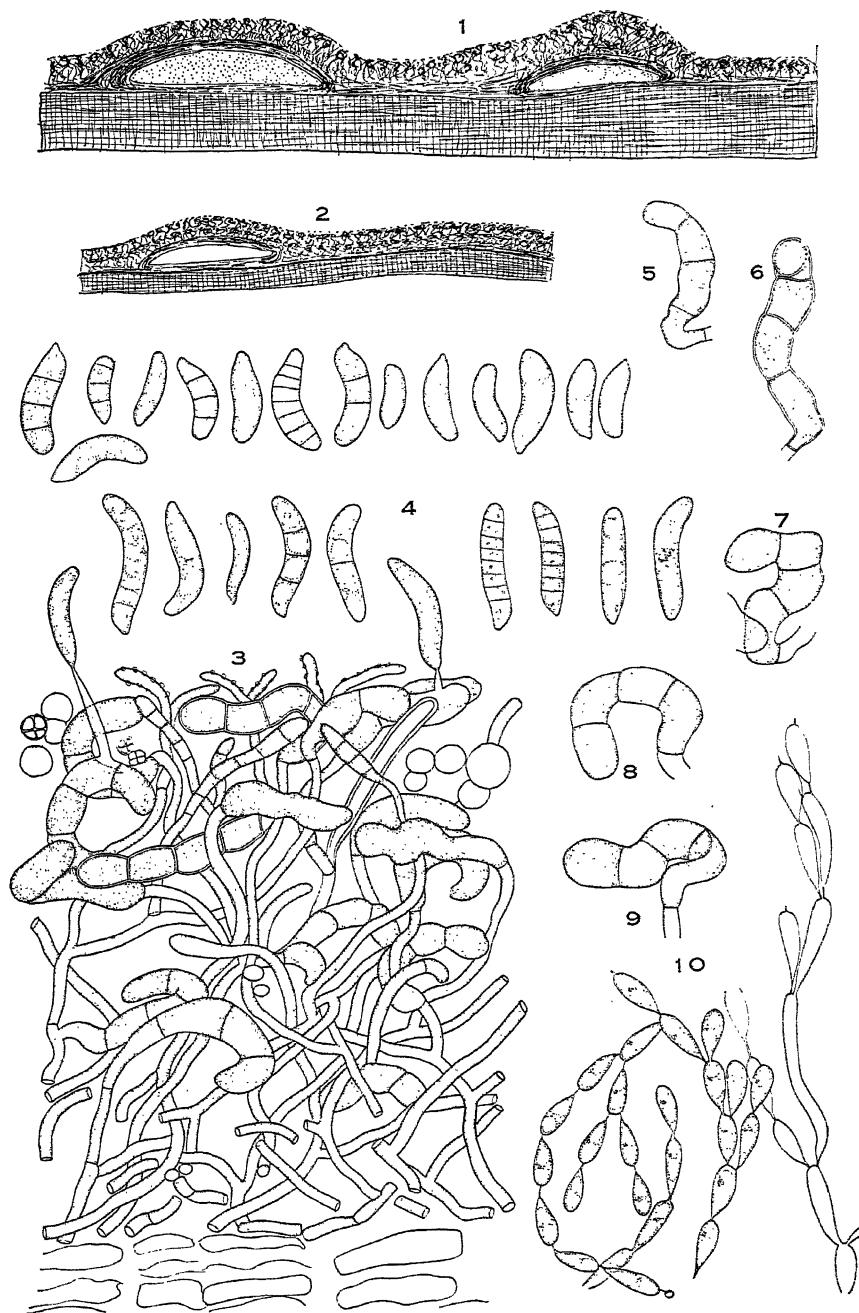


PLATE 38

*S. canescens* Burt.

Fig. 1. Sketch of section through marginal region of fungus, showing hymenium with probasidia and basidia, context, and one parasitized insect.  $\times 33$ .

Fig. 2. Section of hymenial region showing probasidia, basidia, paraphyses, and algal cells.  $\times 833$ .

Figs. 3-6. Basidia.  $\times 553$ .

Fig. 7. Spores.  $\times 553$ .

Fig. 8. Haustorium of "glomerulus" type. All figures from type material.  
 $\times 833$ .

PLATE 38

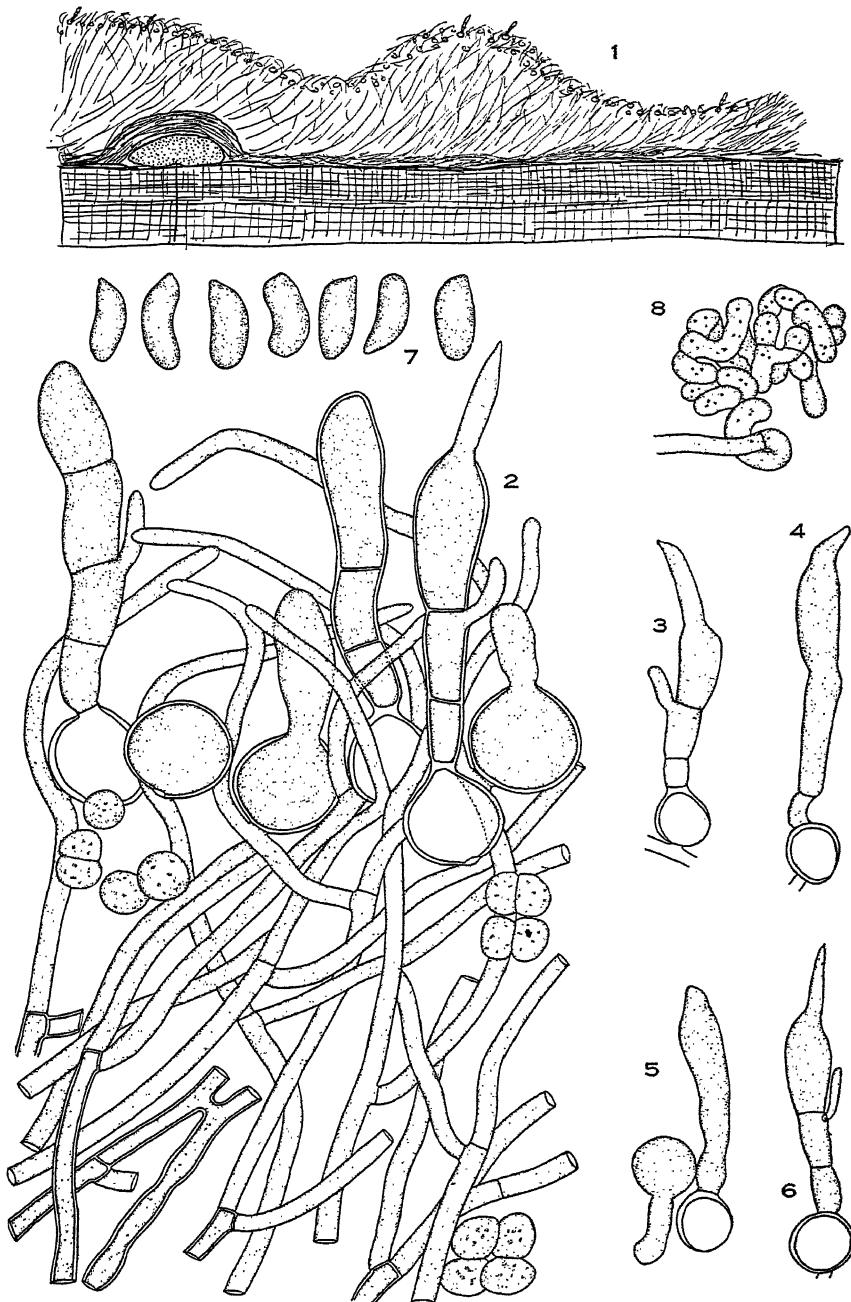


PLATE 39

Figs. 1-10. *S. apiculatum* n. sp.

Fig. 1. Section of fungus showing stratified condition. No mound or apicules shown.  $\times 33$ .

Fig. 2. Hymenium showing probasidia (?), basidia and spore.  $\times 833$ .

Fig. 3. Spores. No. 9302.  $\times 833$ .

Figs. 4-9. Probasidia and basidia.  $\times 833$ .

Fig. 10. Haustoria.  $\times 833$ .

Figs. 11-12. *S. Cokeri* n. sp.

Fig. 11. Probasidia and basidia, the middle probasidium showing internal proliferation.  $\times 700$ .

Fig. 12. Spores.  $\times 700$ .

PLATE 39

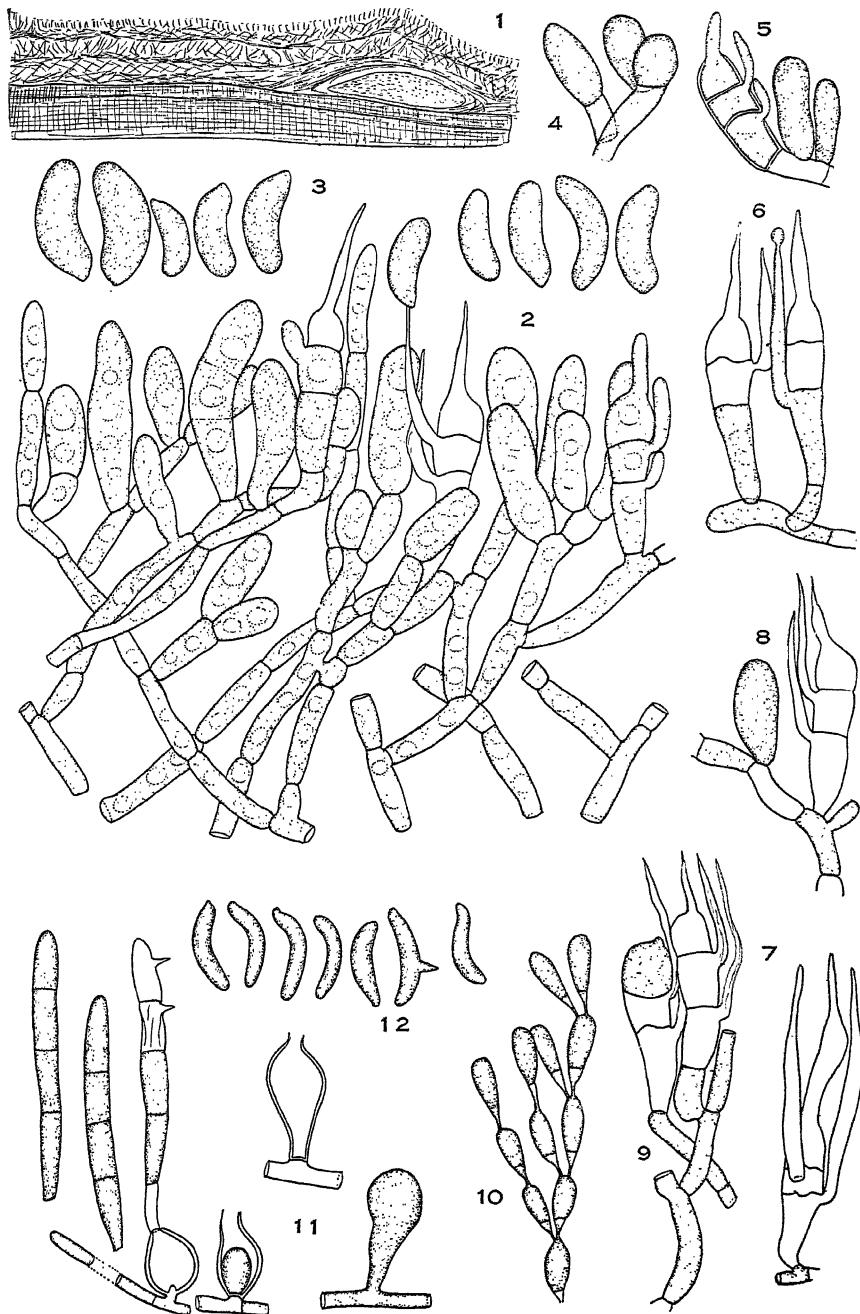


PLATE 40

*S. sabalis* n. sp.

Fig. 1. Section of fungus showing three horizontal layers, scale insects between subiculum and middle layer. Note basidia at surface of top layer.  $\times 23$ .

Fig. 2. Hymenium showing probasidia, basidia, paraphyses, and spore.  $\times 833$ .

Fig. 3. Spores.  $\times 833$ .

Figs. 4-6. Basidia.  $\times 833$ .

Fig. 7. Haustorium.  $\times 833$ .

PLATE 40

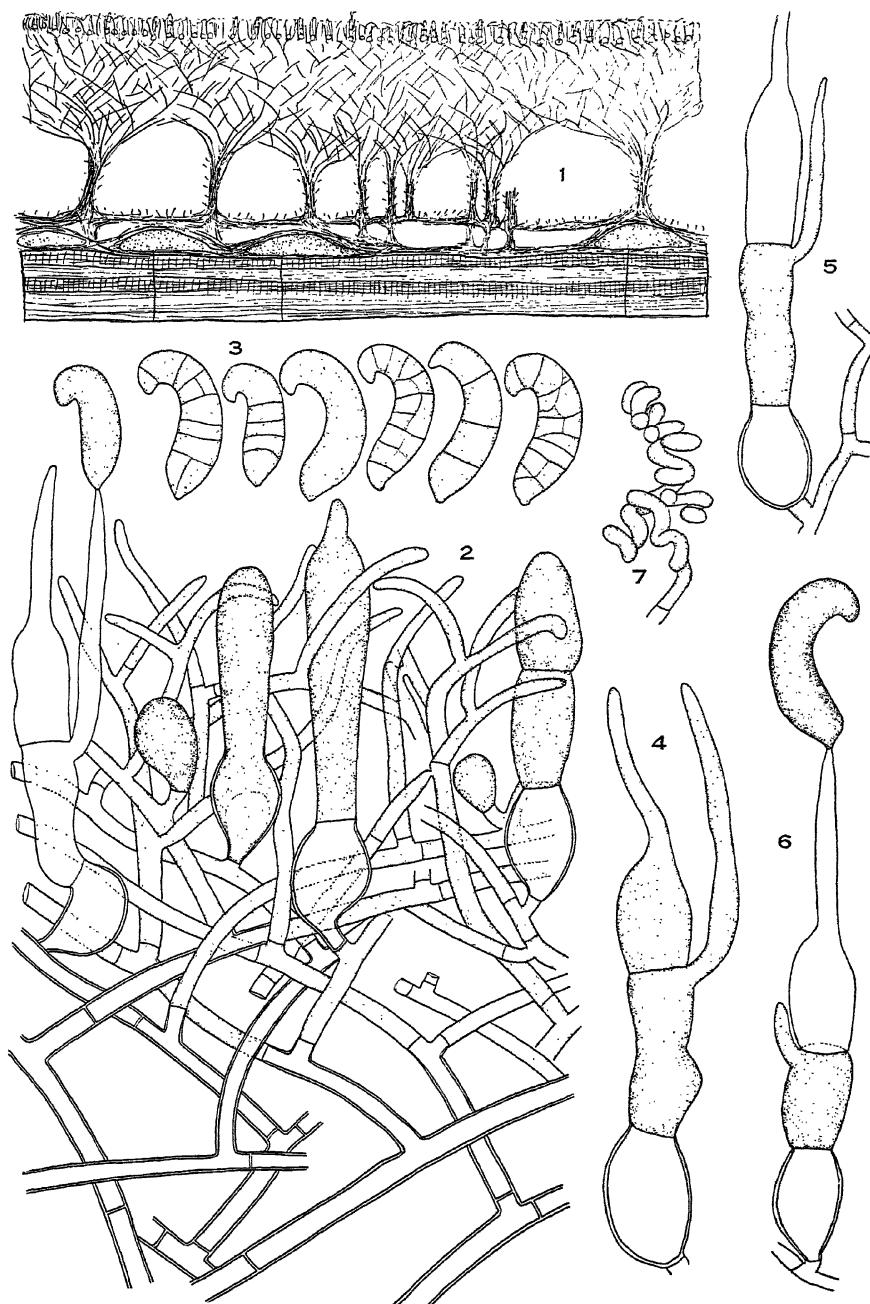


PLATE 41

*S. Langloisii* Pat.

- Fig. 1. Surface view showing marginal condition. No. 9196.  $\times 9$ .
- Fig. 2. Section of context showing hymenium and scale insects.  $\times 33$ .
- Fig. 3. Hymenium showing upright (hyaline) paraphyses, probasidia, basidia, and spores. Daytona Beach, Fla. Thaxter, coll.  $\times 833$ .
- Figs. 4-6. Probasidia and basidia. No. 9196.  $\times 833$ .
- Fig. 7. Basidium and three spores of type. No. 2995.  $\times 833$ .
- Fig. 8. Haustoria. No. 9196.  $\times 833$ .
- Fig. 9. Spores. No. 9196.  $\times 833$ .

PLATE 41

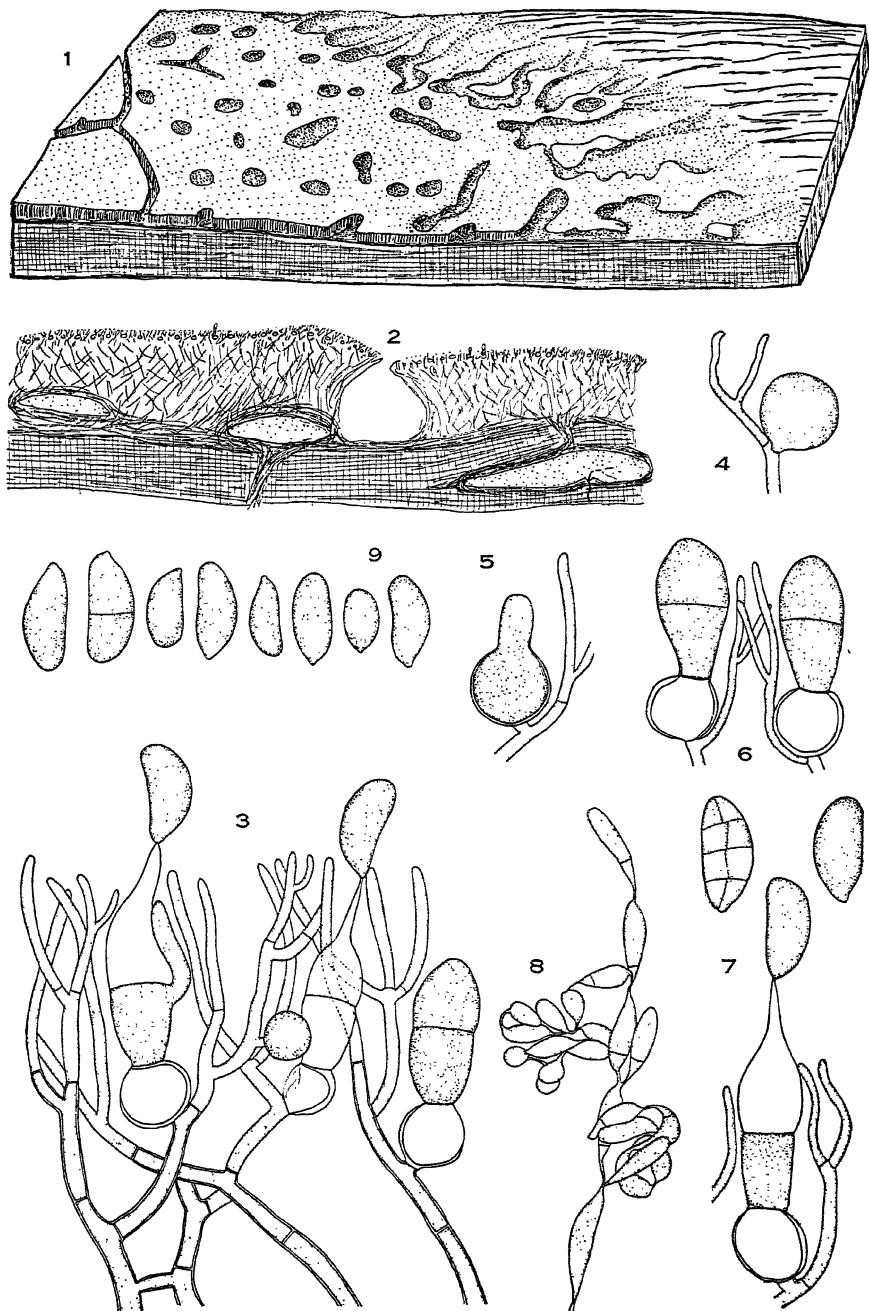


PLATE 42

Figs. 1-5. *S. Patouillardii* Burt.

Fig. 1. Section of fungus in marginal region, showing top layer, pillars, subiculum, and one parasitized scale insect.  $\times 33$ .

Fig. 2. Hymenium showing upright, dark colored, thick-walled paraphyses, probasidia (?), basidia, and spores.  $\times 833$ .

Fig. 3. Spores.  $\times 833$ .

Fig. 4. Basidium and paraphyses.  $\times 833$ .

Fig. 5. Haustoria of irregular coiled type.  $\times 833$ .

Figs. 6-13. *S. taxodii* n. sp.

Fig. 6. Section through fungus showing insect covered by thick upright hyphae.  $\times 33$ .

Fig. 7. Paraphyses from hymenium.  $\times 833$ .

Fig. 8-13. Probasidia and basidia.  $\times 833$ .

PLATE 42

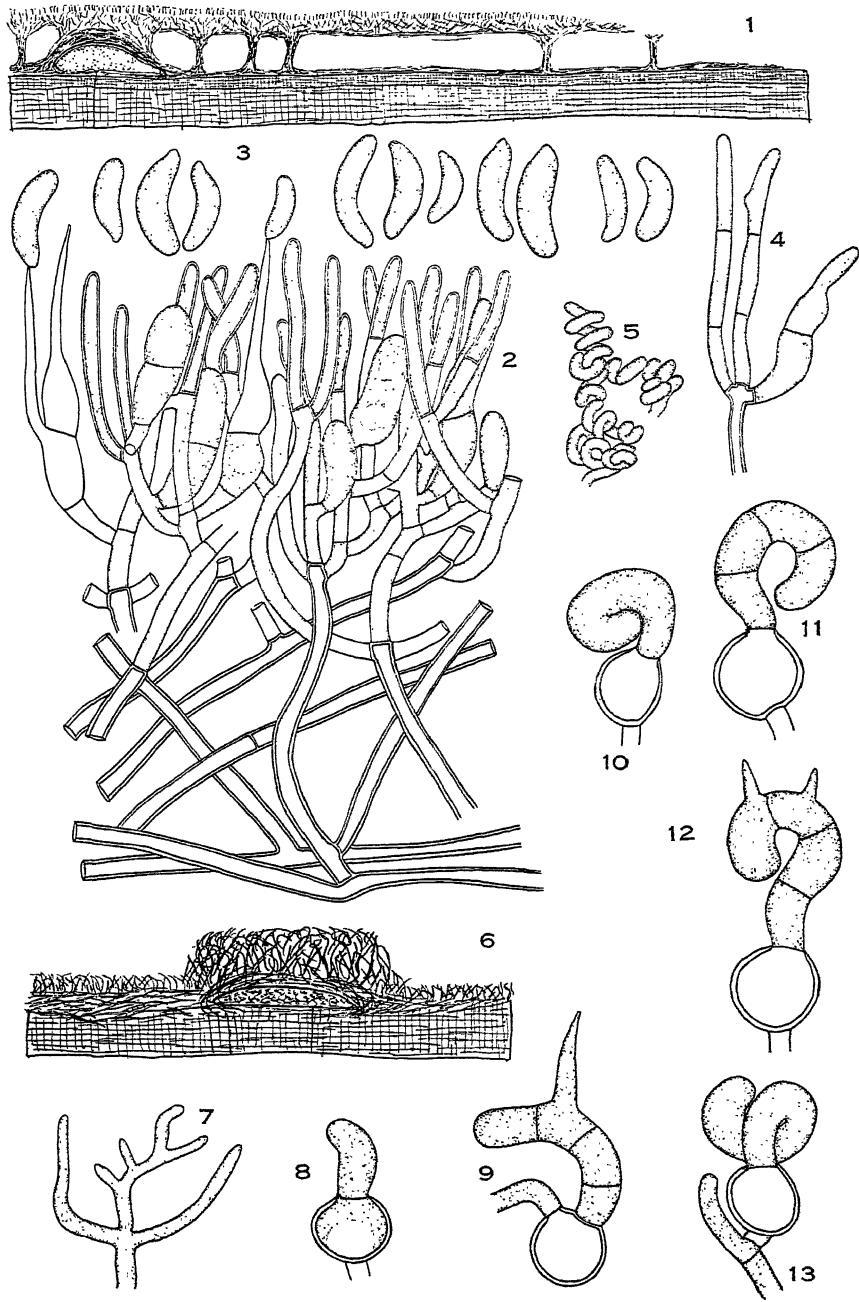


PLATE 43

*S. grandisporum* n. sp.

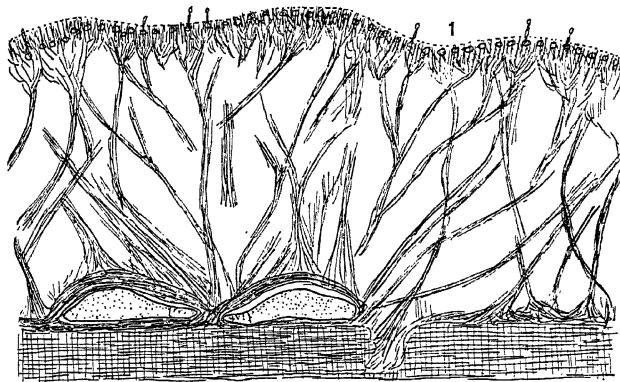
Fig. 1. Section of fungus showing hymenium, branching and anastomosing pillars, and scale insects.  $\times 18$ .

Fig. 2. Hymenium with upright paraphyses, probasidia, and basidia.  $\times 833$ .

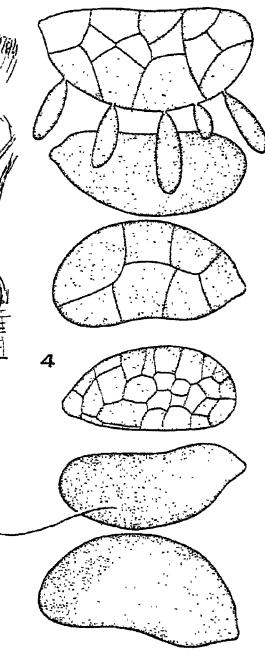
Fig. 3. Basidia.  $\times 833$ .

Fig. 4. Spores, three of which have become divided into numerous small cells, the upper spore forming bud cells.  $\times 833$ .

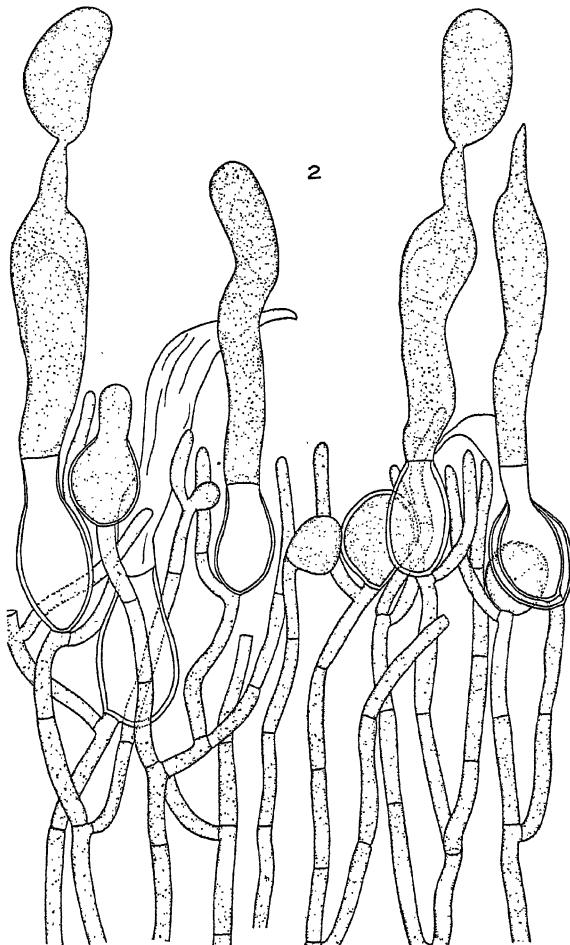
PLATE 43



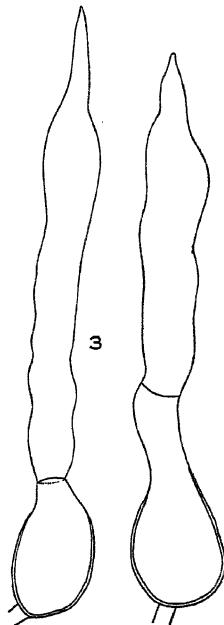
1



4



2



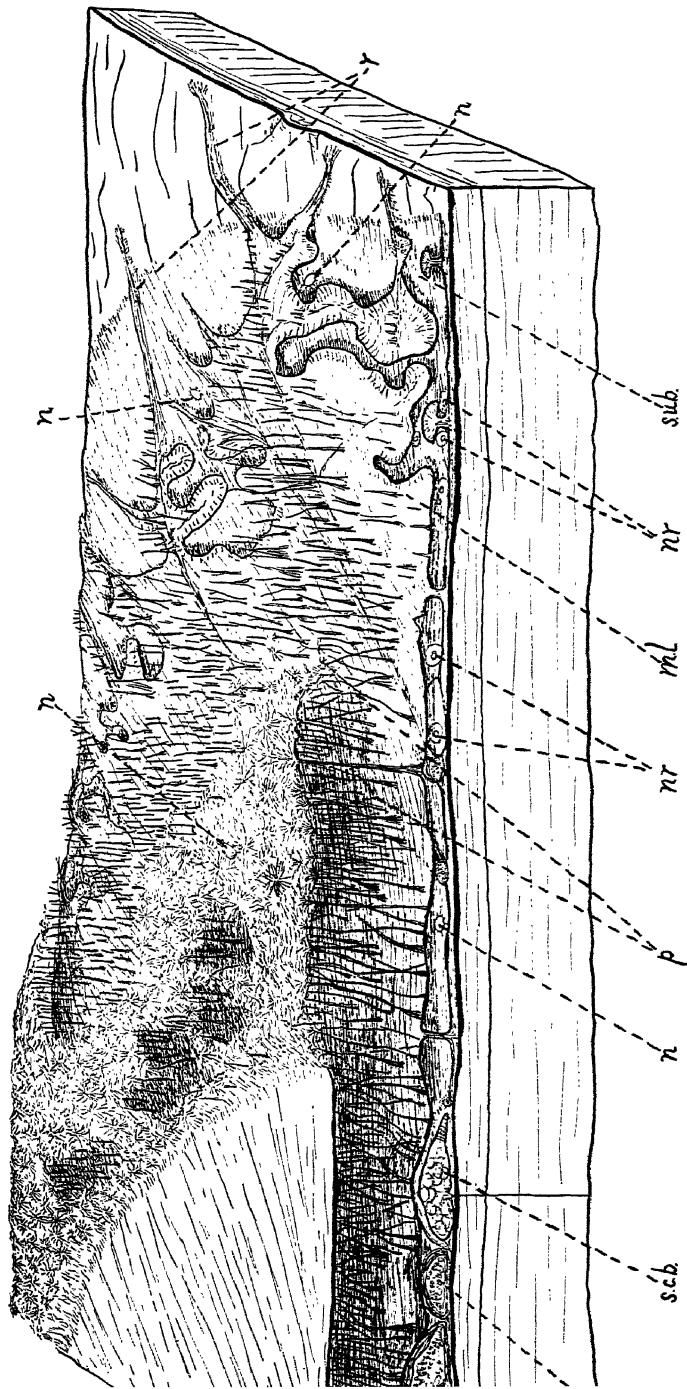
3

PLATE 44

*S. Mariani* Bres.

Sectional and surface view of fungus at time when young are being born. Note three horizontal layers (1) subiculum (sub), (2) middle layer (m.l.) and (3) the top layer (t. l.) which may sometimes be stratified. Scale insects inhabit region between middle layer and subiculum, if insects are parasitized, or between the middle region and bark, if insects are healthy. One healthy adult female (s.c.b.) is giving birth to young, several of which can be seen crawling about over the fungus (n). Some have settled down on the subiculum (n.r.). Rhizomorphs (r) are distinct, also pillars (p). Several insects are parasitized by fungus (s.c.p.).  
× 20.

PLATE 44





## STUDIES ON VIRGINIAN TRICLADS

By ROMAN KENK

### PLATE 45 AND 21 TEXT FIGURES

There is but little information on fresh-water triclad or planarians (*Probursalia* or *Tricladida paludicola*) in Virginia available in literature. The only data I was able to find were the following: Girard (1852, p. 211) established the occurrence of *Dugesia Foremanii* (see *Curtisia foremani*) in Virginia, in the vicinity of Washington, D. C. Kepner and Rich (1918) studied the reactions of the proboscis of "*Planaria albissima*" (see *Fonticola morgani*) collected in the vicinity of the University of Virginia. Taliaferro (1920, p. 63) collected *Planaria maculata* in the same place. Kepner and Pickens (1925, p. 237) give some information on *Trichodina Steinii* found upon the surfaces of "*Planaria polychroa*" (? see *Curtisia foremani*) which had been collected also near the University of Virginia.

In view of the scantiness of our knowledge of the planarian fauna in Virginia, and the southern states generally, I gladly seized the opportunity to study the distribution of this group in Virginia, I being at the time occupied chiefly in physiological research. The account given in this paper is, of course, far from being complete. There still remains much work to be done in this direction. A great part of the country is still unexplored with regard to the occurrence of planarians (see map, Fig. 29).

In this paper I have also included observations on the morphology and ecology of the animals studied. I have tried to supplement the data given by previous authors whenever it seemed desirable. It has been repeatedly pointed out that for the experimental worker an intimate knowledge of his material, particularly an exact identification of the animals, is of great importance. From this point of view, the present contribution may be considered an attempt to secure a basis for further physiological investigations on planarians from Virginia.

Most of the work dealt with in this paper was carried out at the Miller School of Biology, University of Virginia, during the session of 1931-1932. It was continued and concluded at the Department of Zoology, University of Ljubljana, Yugoslavia. I take the opportunity to acknowledge my deep indebtedness to the Rockefeller Foundation which

enabled me to spend a year at the University of Virginia. I also wish to express my appreciation of the many privileges extended to me by Dr. William A. Kepner and Dr. Ivey F. Lewis of the Miller School of Biology. My best thanks are due to all those who assisted me in procuring material from many localities in the state or were in other ways helpful to me. I am particularly indebted to Miss Ada A. Blanco who kindly took charge of the cultures of planarians after my departure from America.

In the taxonomic arrangement of the animals I have, in the main, followed the latest revisions of fresh-water tricladids (Kenk, 1930b, and Hyman, 1931b). Two species and one variety appear to be new or, at least, hitherto undescribed.

*Curtisia foremani* (Girard).

For earlier accounts of this species see Hyman (1931b, p. 322).

THE EXTERNAL FEATURES are already well described by former investigators. I only wish to refer to Figures 1 and 9, a photograph, and a sketch of the living animal.

REPRODUCTIVE ORGANS: I have only a few details, though important ones, to add to Curtis's (1900a) excellent description of the reproductive system. The species stands out in several peculiarities, among which the exceedingly small number of testes and the lobate shape of the ovary are the most interesting. The copulatory apparatus (Fig. 15) is strikingly small. The atrial cavity does not form definite compartments, such as are distinct in some other planarians, and therefore ought to be considered a combination of the male and common atria. The atrium is connected with the genital pore by a narrow canal. The penis consists of a feebly muscular bulb and a finger-shaped papilla or penis proper. The vasa deferentia open separately into the upper part of the penis cavity or seminal vesicle situated in the penis bulb. Posteriorly, this cavity leads into a narrow ejaculatory duct which opens at the point of the penis. More extensive data on the histology of these organs may be found in Curtis's paper. I merely illustrate their general structure, with particular regard to the musculature, in a diagrammatic figure (Fig. 15).

An important fact that has been overlooked by Curtis (1900a, p. 456) and Stevens (1904, p. 210) is the existence of a genito-intestinal communication in this species. Curtis states that the bursa copulatrix ("uterus") lacks an enlarged cavity and that it is blindly closed anteriorly.

In all of my slides I see the bursa stalk opening directly into the

intestine. The two posterior intestinal rami bear branches not only on their lateral sides, but also on the medial sides (a similar branching has also been found in several other triclad). In the postpharyngeal region these medial branches are comparatively well developed and approach the median line rather closely. At the level of the copulatory organs they usually lie dorsally to these. The bursa stalk, starting from the posterior and dorsal part of the genital atrium, first runs dorsally. The common oviduct opens from behind into a small enlargement of it ("uterus," Stevens). The walls of this widened portion are perforated by numerous outlets of eosinophilic shell glands. From here the bursa stalk continues anteriorly and more or less laterally and connects with one of the medial branches of the intestine already mentioned. This part of the bursa stalk ("uterus," Curtis) varies in length and position and usually turns towards the right, more rarely the left, side of the body to lead into a branch of the same side. Occasionally it even connects with two branches, one of the right and one of the left side. On account of the position and histological structure this duct evidently corresponds to a true bursa stalk and not to a modified bursa copulatrix ("uterus"), as Curtis assumes.

At the transitional point between the bursa stalk and the intestinal branch I did not find any particular structures. The lumen of the stalk apparently does not continue directly into the intestinal cavity, but is shut off practically by the close contact of the cells of the intestinal epithelium. Nothing in the nature of a sphincter is developed.

Recently, several authors have discussed the morphological and physiological rôle of the genito-intestinal communications found in a number of Turbellaria (see particularly Steinböck, 1924, and Reisinger, 1929, p. 61-64). Without attempting to recapitulate their assumptions and conclusions more fully I want to state that the conditions observed in *Curtisia foremani* agree perfectly with Steinböck's theories. Steinböck assumes that the bursa copulatrix of the triclad originated (phylogenetically) from a portion of the intestine. Even now it shows a similar structure and, to a certain degree, performs a function similar to that of the latter.

The function of the bursa has been often and amply discussed in the literature concerned. I will merely refer to Graff's (1912-1917, p. 3101-3110) critical review of the facts observed and the hypotheses expressed by various authors on this subject. One fact appears to be well established, viz. that in many triclad the bursa receives sperm from the co-copulant during copulation. Later on the sperm, or at least a part

of them, enter the oviducts and proceed towards the ovaries. Finally they reach the widened anterior parts of the oviducts ("tubae" or seminal receptacles) where they are deposited. Often superfluous sperm are resorbed in the bursa and other parts of the genital tract (Černosvitov, 1931).

*Curtisia foremani* is, apparently, an exception to this general rule in planarians. In copulation the relatively small penis is inserted into the posterior part of the bursa stalk ("vagina") of the co-copulant. Its point may penetrate as far as the small widening of the stalk where the oviducts open into it. Apparently the sperm immediately enters the common oviduct which in this species is provided with a comparatively wide lumen. Superfluous sperm may be carried off by the anterior part of the bursa stalk and digested in the intestine.

These conditions, differing from those observed in other triclad, give the species a separate position among the planarians. Genito-intestinal communications have been established in other fresh-water triclad as well (in *Euplanaria absoloni*, Komárek, 1919, p. 38, and Steinböck, 1924, p. 490-492; and in several species of the family *Dendrocoelidae*, Beau-champ, 1932, pp. 140, 159, 164, 210, 254). In these instances, there is either a distinct bursa present or, more rarely, the bursa stalk connects with a transverse, postpharyngeal commissure of the intestinal rami. In the latter case (*Eupl. absoloni* and *Acromyadenium maroccanum*) the median part of the commissure generally shows a structure similar to that of the epithelium of a true bursa. It seems significant that *Curtisia foremani*, which entirely lacks a bursa copulatrix, appears in other characteristics as well to be the most primitive species among the fresh-water planarians.

**ECOLOGY AND DISTRIBUTION:** *Curtisia foremani* inhabits cool creeks and is usually found attached to the lower surfaces of stones. It is widely distributed in the United States.

#### Distribution in Virginia:

(1) Virginia, near the boundary line, in the vicinity of Washington, D. C. (Girard, 1852, p. 211: *Dugesia Foremanii*).

(2) ? Kepner and Pickens (1925, p. 237) collected "*Planaria polychroa*" in the vicinity of the University of Virginia, Albemarle County. I assume their species to be identical with *Curtisia foremani*.

(3) Tributary of the Ivy Creek, near Charlottesville, Albemarle County. Swiftly running creek with clean water; bottom stones and mud, without vegetation. January 24 (water temperature 11.7°C.) and February 20, 1932 (7.5°C.): numerous mature and immature specimens and several cocoons collected under stones.

(4) Swamp near Rio, about 3 miles from Charlottesville, Albemarle County. July 6, 1932 (coll. Mr. T. K. Ruebush).

(5) Creek crossing the highway Charlottesville—Keswick, about 5 miles from Charlottesville, Albemarle County. Swiftly running, not very clear, water; bottom muddy, with stones. March 20, 1932: one mature specimen collected under a stone.

(6) Creek crossing the highway Charlottesville—Keswick, about  $7\frac{1}{2}$  miles from Charlottesville, Albemarle County. Swiftly running water, bottom muddy, with stones. April 17, 1932: one mature specimen collected under a stone.

(7) Creek near Waynesboro, Augusta County. Creek crossing the highway Waynesboro—Mt. Meridian about two miles from Waynesboro, tributary of the South River. Swiftly running, not very clear water; bottom with mud and stones. March 26 and April 3, 1932: numerous immature and mature specimens collected.

(8) Jennings Branch near Turner Ashby Farm, on the highway Staunton—Churchville, Augusta County. Swiftly running creek, water not very clear, bottom with stones. June 15, 1932 (water temperature  $23.8^{\circ}\text{C}.$ ): several young and mature specimens collected under stones.

(9) Tinker Creek at Cloverdale, Botetourt County (about 7 miles northeast from Roanoke, Roanoke County). Swiftly running, not very clean water. April 22, 1932: one mature specimen collected under a stone.

(10) Outlet of the (artificial) lake at the Girl Scout Camp of Richmond, near Bon Air, Chesterfield County. July 23, 1932: several young specimens collected under stones.

(11) Creek on the road Newport—Mountain Lake, about two miles from Newport, Giles County. August 8, 1932: several immature specimens collected under stones.

(12) Small arm of Bullpasture River about 5 miles below McDowell, Highland County. June 6, 1932: several immature and mature specimens and cocoons collected under stones.

**REPRODUCTION, DEVELOPMENT:** In the laboratory the animals, if well fed, are easily induced to deposit egg-capsules. These are round (diameter 1.27–1.7 mm.) and provided with a thin, often filiform and curved stalk. At the end of the stalk there is a small disc consisting, apparently, of the same substance as the stalk. By this disc the stalk is attached to the substratum. The stalk is soft and does not keep the cocoon in an upright position; it merely anchors the egg capsule.

At indoor temperature the young animals hatch about 12 days after the cocoon has been laid.

#### *Euplanaria tigrina* (Girard)

Synonyms: *Planaria maculata* Leidy, 1847b.

(non *Planaria maculata* Fabricius, 1826: a rhabdocoel.)

(non *Planaria maculata* Darwin, 1844: a terricole triclad,  
*Geoplana maculata*.)

(non *Planaria maculata* Dalyell, 1853: a polyclad.)

*Dugesia maculata* Girard, 1851.

*Euplanaria maculata* Kenk, 1930b.

*Planaria tigrina* Girard, 1850.

*Euplanaria tigrina* was first described by Leidy (1847b) under the name *Planaria maculata*. Girard (1851) transferred the species to his new genus *Dugesia* which, however, has not been recognized by later authors. Recently, since the taxonomic position of planarians has been established according to their anatomical features, this species ranks with the genus *Euplanaria*.

So far it has been overlooked that the name *Planaria maculata* had been already used by Fabricius (1826, p. 34) and Darwin (1844, p. 246) for other species of Turbellaria, before Leidy's paper was written. The name of our animal ought, therefore, according to the International Rules of Zoological Nomenclature,<sup>1</sup> to be rejected as a homonym. In our case this is a very inconvenient demand, because the species belongs to the commonest of North American planarians and is one of the most popular subjects of physiological investigations. It is mentioned in an exceedingly large number of experimental papers and text-books, usually under the name of *Planaria maculata*. Nevertheless, seeing that a yet greater confusion in zoological nomenclature can be avoided only by strict observance of the International Rules, I recognize the necessity of rejecting the preoccupied name *maculata*. Dr. L. H. Hyman, in a private communication, kindly called my attention to the name *Planaria tigrina* Girard (1850, p. 264) as being the next oldest name of the species. I am, therefore, adopting *Euplanaria tigrina* (Girard) as the valid name.

Several authors have pointed out that the species does not appear uniform, or have attempted to split it up into several distinct species (Sivickis, 1923; Hyman, 1920, p. 405; 1931b, p. 324-326; 1931c). The differences between these forms concern chiefly the size and the proportions of the body, and the color and pattern of the surface. So far it is not easy—as Hyman points out—to draw a definite dividing line between these forms. Unfortunately, *Euplanaria tigrina* frequently occurs in asexual colonies, reproducing by fission. There are only certain localities where sexual animals may be found, usually during the warm season, while in other places a continuous agamic reproduction has been observed for many years (cf. Curtis and Schulze, 1924, p. 105). These facts render it difficult to compare the anatomy of the reproductive organs of animals from different geographical areas, showing slightly differing external features. Such a comparison would be of great assistance in establishing specific differences and giving exact definitions of the various taxonomic units.

Yet a very close relationship between these forms appears to be

<sup>1</sup> See: X<sup>e</sup> Congrès international de zoologie, tenu à Budapest 1927. Annexe, p. 1583-1594. Budapest, 1929.

indubitable. Hyman (1931b) has given a review of the forms concerned: *Euplanaria maculata*, *E. novangliae* Hyman, and *E. microbursalis* Hyman and has united them in a "Euplanaria maculata group" with definitely marked features.

I had an opportunity to investigate sexually mature specimens belonging to this group and obtained from Chicago, Ill., Falmouth, Mass., and Richmond, Va. According to Hyman's classification these animals belong to the species *Euplanaria maculata* and *E. novangliae*. The copulatory organs, however, afforded no means of discriminating between them.

In view of this situation, it would in many cases prove impossible to establish the proper taxonomic position of preserved animals belonging to *Euplanaria tigrina* or *E. novangliae*. Sometimes only the study of living specimens would reveal the slight differences characteristic of the forms in question. We, therefore, may assume that these forms are related closely enough to be united into one species, *E. tigrina*. *Euplanaria novangliae* would consequently have to be considered a subspecies of this species. *Euplanaria microbursalis*, which I did not have for comparison, appears to be a separate species.

THE ANATOMY of *Euplanaria tigrina* has been intensively studied, particularly by Bardeen (1901) and Curtis (1902). I merely want to add a few observations which may supplement and, to a certain extent, correct the descriptions of the reproductive organs given by Curtis (1900b, 1902) and Sivickis (1923). Figure 16 represents a diagram of the copulatory apparatus, with special regard to the arrangement of the muscle fibers. The preparation from which the figure is drawn was made from a specimen from Falmouth, Massachusetts. It was collected in one of the places where Curtis obtained his material (pond south of the road, behind the Episcopal Church). Nevertheless it conforms in all essential features to animals from Richmond, Virginia, and Chicago, Illinois (kindly sent by Dr. Libbie H. Hyman). Hyman (1931b, p. 325) is inclined to consider Curtis's form *E. novangliae*.<sup>2</sup>

It is remarkable that in fully mature animals much of the epithelium of the copulatory organs is "depressed," viz. the nuclei of the epithelial cells are depressed into a deeper layer. This is true for the epithelium

<sup>2</sup> Miss L. H. Hyman, in a private communication, informs me that recently she had made many more sections of sexual specimens of different provenance and cannot find any differences whatever in the reproductive systems. She is now likewise inclined to unite the various forms into one species and even doubts if we can clearly discriminate between definite varieties in that.

lining the male and common atria, the vagina (the posterior part of the bursa stalk), and that coating the penis. Normally developed epithelium (with nuclei in the cells themselves) is found in the canal connecting the common atrium with the genital pore, in a transition area between the two compartments of the atrium, in a small area surrounding the opening of the ejaculatory duct at the point of the penis, and in the anterior part of the bursa stalk (between the bursa copulatrix and the openings of the oviducts).

The two oviducts open into the bursa stalk from the posterior and lateral side. They do not seem to unite before attaining the bursa stalk, but to open independently, though very close to each other.

The "circular groove or furrow" near the point of the penis described by Sivickis (1923, p. 116) is an inconstant feature. It appears to be brought about by the different structure of the epithelium in this place, where the lining of the ejaculatory duct encroaches on the external surface of the penis. In this area the compact muscular layer of the penis wall is lacking. This place, therefore, is mechanically less resistant and appears more or less deformed in the preparations, according to the state of muscular contraction in which the organ has been fixed.

**ECOLOGY AND DISTRIBUTION:** *Euplanaria tigrina* is widely distributed in the United States and is not infrequent in Virginia. Here it lives in smaller and larger pools and ponds, preferring stagnant water. It is found between water plants and on the under surfaces of stones.

#### Distribution in Virginia:

(1) Sinclair's Pond, Park Street, Charlottesville, Albemarle County. August 20, 1931: numerous small specimens brought into the Laboratory with samples of water plants.

(2) Pond on the highway Charlottesville—Lynchburg, near Charlottesville, Albemarle County. September 2, 1931: a few asexual specimens collected between water plants.

(3) Big Spring, near Kerr's Creek, Rockbridge County. A big pond fed by several small springs immediately on its bank. Besides this form, *Fonticola morgani* var. *polycelis*, *Planaria dactyligera* and *Procotyla typhlops* are found in this locality. *Euplanaria tigrina* occurs in the warmer parts of the pond. September 11 and October 11, 1931: numerous asexual specimens collected between water plants.

(4) Mountain Lake, Giles County. Natural lake situated at an altitude of about 4000 feet. Limnological data on this locality have been published by Hutchinson and Pickford (1932). November 23, 1931, and July 7, 1933: one asexual specimen collected under a stone near the north bank.

(5) Trice's Lake, Cumberland County. Artificial lake with shallow water, bottom (near the bank) muddy or sandy, with few stones, here and there rich vegetation. April 26, 1932: several asexual specimens collected under stones.

A few stalked cocoons, mostly empty, were also seen; they probably belonged to this species.

(6) Outlet of Westhampton Lake, University of Richmond, Henrico County. July 23, 1932: numerous specimens of various sizes, part of them mature, and several cocoons collected under stones.

**REPRODUCTION:** In *Euplanaria tigrina* both sexual and asexual reproduction occurs. The type of reproduction and the life cycle may vary in different localities, as has been established by Curtis (1902; Curtis and Schulze, 1924). In Virginia, I collected sexually mature animals only near Richmond; Trice's Lake likewise seems to contain a sexual form of this species during the warm season. From the other localities listed I obtained specimens reproducing by fission. I kept cultures of them for many months without observing any traces of copulatory organs.

Sexually mature lots deposited egg capsules in aquaria. They are spherical and attached to the substratum by a stalk.

Fuller information on the ecology and development of the animals as well as on the keeping of them in laboratories may be found in the papers quoted and in many experimental papers dealing with this species.

#### *Euplanaria dorotocephala* (Woodworth)

In her revision of the North American fresh-water triclad Hyman (1931b, p. 323) establishes a "*Euplanaria dorotocephala* group" which embraces several species closely related to each other, viz., *Euplanaria dorotocephala*, *E. agilis* (Stringer), and *E. philadelphica* Hyman. They differ from each other by the color and pattern, to some degree also by certain anatomical features.

In several localities in Virginia I have collected planarians which belong to this group. Unfortunately, I was not able to induce the development of sex organs in all these lots. The external features of specimens from different lots were slightly different, particularly the details in the arrangement of the body pigment. It is well known that the color of *Euplanaria dorotocephala* is more or less subject to change and is even influenced by the temperature of the water. Therefore, the color of animals kept at indoor temperature for some time cannot always be considered normal (Hyman, 1929, p. 407).

Sexually mature specimens, which I obtained from two cultures, conformed entirely to the general anatomical plan characteristic for the group. Slight differences between individual specimens were presumably due to different stages of maturity or different states of contraction

in the fixing fluid. In general, the animals resembled *E. dorotocephala* rather than *E. agilis*. I may, therefore, assume that my material belonged to that species, which is widely distributed in the central and eastern states.

The relationship between the forms of the *E. dorotocephala* group appears to be similar to that between the representatives of the *E. tigrina* group discussed in the previous chapter. In view of the slightness of the anatomical differences between the various forms it seems advisable to unite them all in one single species, viz. *E. dorotocephala*. The separate forms might be considered subspecies or varieties of this species rather than separate species.

**ECOLOGY AND DISTRIBUTION:** In Virginia *E. dorotocephala* occurs in cool creeks with clean water. It can be collected on the under surfaces of stones. I have never found mature specimens in the field.

#### Distribution in Virginia:

(1) Big Spring, near Kerr's Creek, Rockbridge County. October 11, 1931: numerous specimens collected in the outlet of the big pond (water temperature 19°C.).

(2) Creek near Waynesboro, Augusta County (the same locality as that where *Curtisia foremanii* was collected). March 3, 1932: one specimen under a stone.

(3) Spring at Turner Ashby Farm, close to Jenning's Branch, on the highway Staunton—Churchville, Augusta County. Clean, cold spring, outlet with stones. June 15, 1932 (water temperature 16.1°C.): several specimens.

**REPRODUCTION, DEVELOPMENT:** Both in the field and in the laboratory, *E. dorotocephala* mostly propagates asexually. In the laboratory, at indoor temperature as well as in an ice-box (temperature 10–12°C.) several cultures attained sexual maturity. Specimens from Big Spring laid many cocoons, all of them sterile, however. The cocoon is spherical, with a diameter of about 1½ mm., and provided with a stalk which ends in a disc attached to the substratum (Fig. 20). The stalk is usually somewhat curved, of various lengths (in an extreme case it attained 5 mm.). Freshly deposited egg capsules are milky white; after a few hours they become yellowish, gradually turn reddish brown, and finally, after some days, almost black.

#### *Fonticola gracilis* (Haldeman), n. comb.

Synonyms: *Planaria gracilis* Haldeman, 1840.

*Phagocata gracilis* Leidy, 1847a.

*Euplanaria gracilis* Kenk, 1930b.

The structure of this species has already been intensively investigated by Woodworth (1891) and Peaslee (1910). In these papers, the older

publications on *Fonticola gracilis* are quoted and summarized. Nevertheless, the anatomical descriptions are not complete and, partially, incorrect.

THE EXTERNAL FEATURES of the animal are already well known. I refer to Figures 4 and 10, the first being a photograph of the gliding animal, the latter illustrating the outline of it.

REPRODUCTIVE SYSTEM: The structure of the copulatory apparatus is of great importance to the taxonomist and a great help in the exact identification of planarians. I shall, therefore, give a more complete description of it even at the risk of some repetition.

The genital pore (see Fig. 17) leads into a small cavity into which opens the stalk of the bursa copulatrix; I call it, therefore, the common atrium. Anteriorly a tubiform portion of the atrium proceeds from this cavity, sometimes forms a sigmoid loop and widens into a rather voluminous cavity containing the penis; this cavity is the male atrium.

The epithelium of the anterior part of the male atrium is extremely flattened, but caudally it gradually becomes cubical; a similar cubical epithelium lines the common atrium. Two layers of muscles surround the atrium, a circular and a longitudinal one. Beneath the flattened epithelium of the male atrium the musculature is but little developed and apparently consists only of longitudinal fibers. Posteriorly a circular layer is wedged between this and the epithelium. Both layers are particularly strong in the tubiform posterior portion of the male atrium (Peaslee calls this portion the "muscular tube").

The penis ("spérn receptacle," Peaslee) is a comparatively large and highly complicated organ. It is composed of a relatively small bulb embedded in the parenchyma, and a large papilla, or penis proper, projecting into the male atrium. Both portions are highly muscular. The penis is cone-shaped in the basal part, posteriorly it becomes tubiform, gradually tapering towards the point. This tubiform portion may have a different position in the slides. It is always bent and sometimes even forms several loops, lying either in the enlarged part of the male atrium or protruding into the tubiform section of it. Peaslee, in his Figure 33, draws a part of the papilla telescoped, as it were. I never saw a similar phenomenon in my preparations; apparently it is due to an abnormal retraction of the organ, when the animal was being killed.

The vasa deferentia, after forming a loop on each side of the atrium, enter the penis bulb laterally and ventrally, as Peaslee correctly states. In the penis they run first dorsally, then turn towards the penis proper and gradually converge. They unite, without enlarging, to form a short common vas deferens which proceeds along the main axis of the

penis and opens into a small cavity. This does not exhibit any special glandular differentiation, the lining epithelium resembling the wall of the vasa deferentia. The cavity empties into another, larger one, of different histological structure: the seminal vesicle. The lumen is closely packed with lumps and granules of secretion of faintly eosinophilic nature. This secretion apparently originates in the degeneration of tall columnar or club-shaped cells of the epithelium; between these masses of secretion, remains of disintegrating cells and even nuclei may be observed. This cavity presumably corresponds to the structure called "anterior seminal chamber" by Peaslee.

The outlet of the seminal vesicle is a canal which proceeds through the tubiform section of the penis and opens at its point. The lumen is, in general, relatively narrow, of unequal diameter, i.e. it may be wider or narrower locally. Nevertheless, a constant "posterior seminal chamber," such as Peaslee describes and illustrates, does not exist.

Peaslee states that near the point of transition from the conical, basal, to the tubiform, distal, part the penis is connected "by a ligament-like structure with the walls of the main sheath"—the male atrium—"surrounding the sperm receptacle"—penis. I have not seen any trace of such a structure nor has a similar connection been as yet observed in any other planarian. The observation is apparently erroneous and perhaps due to the fact that, in his preparations, glandular secretion present in the atrium bridged the space between the penis and the wall of the atrium.

The histological structure of the penis is rather complicated: The penis bulb consists of a very dense network of muscle fibers arranged in flattened bundles and forming vaulted layers. The penis proper is coated with an extremely flattened epithelium with sparse nuclei which project a little beyond the general surface. Under the epithelium is a relatively thick layer of fibrous structure (see Fig. 17, *f*), usually stained faintly pink in the preparations and therefore well marked off from the muscular fibers. In tangential sections two systems of fibers may be observed in this layer, running parallel to the surface of the organ and obliquely to its main axis, crossing each other diagonally. Several strata of such fibers alternate in the fibrous layer. They most likely represent the structure described by Woodworth as "alternating layers of circular and longitudinal muscles, five of each, forming a thick zone" (1891, p. 32). They do not, however,—as already mentioned—react towards histological stains like muscle fibers and also are much thinner than these. Presumably they belong to the same category of tissues

as similar fibrous structures occurring in a similar position in *Dendrocoelopsis spinosipenis* (Kenk, 1925, p. 141). Their function seems to be mechanical, though entirely passive, giving a certain resistance and elasticity to the wall of the penis and serving as a base for the attachment of muscles.

Under the fibrous layer, the network of muscles in the penis bulb continues into the penis proper up to the level of the seminal vesicle. In the narrow, distal, part it is, however, substituted for by (chiefly) longitudinal muscles which are extended in the space between the fibrous layer and the epithelium of the ejaculatory duct.

The bursa copulatrix is a relatively large, more or less lobate, sac lying close to the pharyngeal chamber. Often the latter even extends backwards on both sides of the bursa and in the space between this and the ventral body wall (Fig. 17). The bursa stalk ("vagina," Woodworth; "uterine duct," Peaslee) runs on the right side of the penis in all my preparations, while Woodworth and Peaslee indicate that it runs on the left side. The stalk becomes wider posteriorly. It is formed by an epithelial lining coated with two layers of muscle fibers, a circular and a longitudinal one. The wide posterior part of the stalk, which exhibits a stronger musculature, may be distinguished from the anterior portion as a "vagina."

The two oviducts run posteriorly above the ventral nerve cords. At the level of the copulatory organs they turn medially, the left one passing under the bursa stalk. They unite above the posterior part of the tubiform section of the male atrium and by means of a short common oviduct open into this. Peaslee's Figures 32 and 33 show the oviducts embracing the bursa stalk. This does not occur. Woodworth's indication that the oviducts empty into the bursa stalk is likewise incorrect.—Numerous shell glands open into both oviducts in their sections between the point where they leave the nerve cords and the point of fusion, as well as into the upper part of the common oviduct.

**ECOLOGY AND DISTRIBUTION:** *Fonticola gracilis* has been found in several springs and spring-fed ponds in Virginia. It is, however, well known that the species occurs frequently in stagnant water as well. It may be collected on the lower surfaces of stones, between dead leaves lying in the water, and on water plants.

#### Distribution in Virginia:

(1) Spring near the railroad depot at East Radford, Montgomery County. The spring is cased and covered and has clean water. Outlet with muddy bottom. December 6, 1931 (water temperature 10°C.): numerous, mostly mature, specimens collected on dead leaves and stones.

(2) Spring near Endless Caverns, Rockingham County. Limestone spring on Endless Caverns Farm, 2 miles south from New Market. Clean, almost stagnant water with rich vegetation; bottom with stones. June 24, 1932: very numerous, mature and immature, specimens collected under stones.

(3) Lacey Spring, Rockingham County. Large limestone spring, artificially altered; bottom muddy with few stones, at the edge a rich vegetation of water-mosses. June 24, 1932: numerous, mostly immature, specimens brought into the laboratory with water plants.

TAXONOMIC POSITION: Since Leidy (1847a) created a separate genus, *Phagocata*, for this species, it has usually been called *Phagocata gracilis* in literature. The genus *Phagocata* was based chiefly on the presence of many pharynges in the animal. Later on, when several European polypharyngeal species were described, this feature lost its significance. On account of the description of the reproductive organs given by Woodworth (1891) the species was recently included with the genus *Euplanaria* (Kenk, 1930b). Woodworth (p. 35) states that "the oviducts open into the vagina just above the point where it enters the genital atrium" and in his Figure 42 shows them entering the bursa stalk separately. As has been shown in a previous chapter, they first unite, and then by a short common oviduct empty into the atrium. Because of this characteristic the species ought to be classed with the genus *Fonticola*. It differs, however, from most of the other species of this genus by a number of anatomical features, especially by the complicated structure of the penis. Should the genus *Fonticola* eventually be divided into several taxonomic groups, *F. gracilis* would require a group to itself and Leidy's name, *Phagocata*, would have to be restored with a new definition.

***Fonticola morgani* (Stevens and Boring) n. comb.**

Synonyms: *Planaria truncata* Leidy, 1851.

(non *Planaria truncata* Abildgaard, 1789: a rhabdocoel.)

*Dendrocoelum truncatum* Girard, 1894.

*Planaria morgani* Stevens and Boring, 1906.

*Fonticola truncata* Hyman, 1931b.

Leidy (1851) was the first to describe the external features of this species, giving it the name of *Planaria truncata*. Then the species was lost sight of for more than half a century, until, in 1906, Stevens and Boring published a short description of what they believed to be a new species, *Planaria morgani*. Stringer (1918, p. 358) established the identity of the forms described in both papers and restored the older name given by Leidy. The name *Planaria truncata*, however, had

already been used by Abildgaard (1789, p. 43) to designate a rhabdocoel, *Castrella truncata*. Therefore, this name is to be rejected as a homonym and the newer name *morgani* again becomes valid.

*Fonticola morgani* is widely distributed in Virginia and ranks among the commonest planarians of this state. The species presents a considerable variability in the external appearance as well as in the anatomy. At first, when I had studied animals from a few localities only, it seemed to me that one ought to distinguish at least two different forms. Subsequently, I had the opportunity to investigate specimens from 18 different localities in serial sections and to compare them with material from Cold Spring Harbor, New York, kindly sent me by Dr. William A. Castle. It then appeared that the differences existing between the extreme forms are bridged over by gradual transitions in the characteristics. I shall have to return to this question later on, in the review of the anatomical structure.

There is, therefore, no reason to call these diverging forms different species; it would be very difficult to discriminate between them with a reasonable degree of certainty. Animals collected in the same locality, however, exhibit a considerable uniformity. It seems very probable that the species *F. morgani* is in process of splitting up into several species. One could talk of a "*Fonticola morgani* group" in a similar way as Hyman (1931b, p. 323 and 324) establishes a *Euplanaria maculata* group and a *E. dorotocephala* group. We also find analogous conditions in other species of the genus *Fonticola*, viz., *F. vitta* and *F. albissima* (see Beauchamp, 1932). Unfortunately, the variability of specific characteristics in the fresh-water triclad has been but little investigated.

In cases like this, the taxonomic units of secondary significance hardly should be given the rank of distinct species. The differences between the animals are often so subtle that only an extensive comparison can lead to a correct interpretation of their taxonomic position. A sure identification is rendered very difficult, particularly in animals so plastic and changeable in shape as planarians are. It is preferable by far to call them subspecies or varieties of the same species. Thus not only their presumable relation to each other would be clearly indicated, but also much confusion would be saved, which is otherwise liable to arise from the use of the wrong specific name by workers who are not particularly familiar with the taxonomy of the group.

**EXTERNAL FEATURES** (Figs. 6 and 11): The length of sexually mature specimens ranges from about 10 to 17 mm., the greatest width from 1.3 to 2.3 mm., the average being 14 and 2 mm., respectively. Specimens

from different localities may present certain constant differences in the dimensions of the body, which remain even after they have been kept in the laboratory for several months under the same external conditions.

The body is unpigmented and appears white when the intestine is empty. After feeding, the contents of the intestine show through; freshly collected specimens usually show a brownish, or grayish, or reddish, more rarely a greenish intestine. All regions which are free from intestinal branches, are always white—the anterior and marginal parts, the regions of the pharynx and of the copulatory apparatus.

The anterior end is truncated. The frontal profile is almost straight or slightly concave or convex, altering rapidly in outline when the animal performs groping movements. Laterally the front margin forms indistinct and rounded auricular appendages; these are kept somewhat raised during locomotion. Behind them, a very slight and insignificant narrowing of the lateral margins ("neck") may be discerned when the animal is moving. Then the margins diverge gradually to attain the greatest width at the level of the pharynx; then they converge again and meet at the more or less pointed posterior end.

In fully grown specimens the anterior end of the pharynx is situated at about the middle of the body length or a little more anteriorly. The length of the pharynx is from one-sixth to one-fifth of the entire body length. The copulatory apparatus occupies about the anterior half of the postpharyngeal region.

Usually two small eyes are present. In mature animals their distance from each other is from one-fourth to one-third of the body width at the eye level, in young animals even less (one-fifth). The distance from the front margin is smaller than the body width in big animals, while in young specimens it may be greater than the latter. Supernumerary, "secondary," eyes may occur, usually only one on one side. Specimens from certain localities, however, show an exceedingly enlarged number of eyes. I have separated these forms from the type of the species and shall describe them as a variety, var. *polycelis* (see p. 103).

THE SURFACE EPITHELIUM is constructed on the usual plan. Submarginally, a continuous zone of openings of heavily eosinophilic glands ("adhesive zone") encircles the entire body. The gland cells proper are situated in the deeper layers of the parenchyma, while the outlets perforate a strip of modified cells in the surface epithelium. These cells, or at least most of them, show the nuclei depressed into the underlying parenchyma. They also contain only few rhabdites.

On the ventral side of the head, behind the adhesive zone, a narrow

(only a few  $\mu$  broad) strip of depressed epithelium follows the median line for a short distance (about  $170\mu$ ). The cells here lack rhabdites and are apparently perforated by the ducts of feebly cyanophilic glands. I have not succeeded in establishing the function of this organ (a primitive adhesive organ?).

**DIGESTIVE SYSTEM:** The comparatively large pharynx or proboscis shows the structure distinctive for the family *Planariidae*: its inner muscular zone consists of two separate layers of muscular fibers, a circular (immediately under the inner epithelium) and a longitudinal one. The external muscular zone is also formed by a longitudinal and a circular layer, while a second (internal) longitudinal layer, such as is developed in certain planarians, is absent.

The three intestinal rami are provided with numerous lateral branches which, in their turn, are secondarily ramified. The two posterior rami are mostly entirely separated from each other; in rare cases they are connected by anastomoses. They bear short branches also on their medial sides. The number of the intestinal branches varies to a considerable extent and increases with the increasing size of the animal. Sexually mature specimens have from 7 to 13 branches on each side of the anterior ramus and from 15 to 27 branches on the lateral side of each posterior ramus. On account of the profusely branched intestine it is sometimes difficult to investigate the ramification in living animals. Perhaps the numbers given do not represent the maximum. The formula of the intestinal ramification, as it is usually written by German authors, is as follows: 15-27, 2(7-13), 15-27.

**SENSE ORGANS:** Besides the eyes there are auricular sense organs present. These cannot be recognized in living specimens; they are, however, distinctly discernible in the slides. They form a pair of marginal strips of "depressed" epithelium, without rhabdites, situated on either side of the head. It is not easy to establish the exact position from the cut sections, as the anterior end is more or less deformed in fixing; but presumably they occupy parts of the front margin and of the margin of the auricular appendages. The middle part of the front margin, to the length of about  $\frac{1}{3}$  mm., is free from these organs. The medial ends are narrow and placed exactly at the edge of the margin; laterally the organs widen and to a certain extent pass over to the dorsal surface. Between these strips and the submarginal adhesive zone there intervenes a band of normal, rhabdite-bearing epithelium, similarly widening towards the lateral region.

**REPRODUCTIVE SYSTEM:** The testes are numerous, of various size,

round or polyhedral. Most of them are situated near the ventral body wall, rarely do they approach the dorsal surface by penetrating the parenchyma between the intestinal branches. It seems, however, that the latter position is caused only by lack of space. On each side of the body they form a longitudinal zone, the median area being free from them. Each zone of testes begins anteriorly at about the level of the ovaries (occasionally even in front of them) and extends posteriorly to the level of the mouth. Laterally they reach to about the place above the ventral nerve cords. In transverse sections one to five testes may be found on each side of the intestine in fully mature specimens (Fig. 24).

From the testes start fine *vasa efferentia*, thin-walled tubes which may be observed only in very good sections. They lead into a narrow longitudinal canal, the *vas deferens*, that proceeds in a more or less curved course along the medial side of each ventral nerve cord, somewhat higher than the muscular layers of the body wall (Fig. 24). Posteriorly each *vas deferens* widens to form enlarged and coiled tubes, the false seminal vesicles; these attain a more dorsal and medial position than the thin anterior parts of the *vasa efferentia*. They are easily found in the preparations, being filled with sperm. Towards the copulatory organ they narrow gradually and enter the penis bulb on its lateral sides.

A pair of ovaries or germaries is situated on the inner sides of the nerve cords at a short distance behind the cerebral commissure. Their structure conforms to the usual plan. Laterally and dorsally to each ovary, sometimes penetrating far towards the dorsal surface, lobate or funiciform masses of cells are situated; these may be compared to the "parovaria" of certain planarians. They consist of large rounded cells with round, darkly staining nuclei of granulated structure, resembling young undifferentiated yolk cells. Occasionally one may find shell-droplets in their protoplasm, such as are normally seen only in yolk cells.

The oviducts spring from the dorsal surfaces of the ovaries. They start as somewhat enlarged funnels ("tubae") which contain sperm (seminal receptacles). Soon they become narrow ducts, running posteriorly near the dorso-lateral side of each nerve cord, but not always closely adjacent to it (Fig. 24). In their main portion they are connected with vitellaria or yolk glands. The latter are distributed generally over the parenchyma, occupying chiefly the lateral and dorsal regions of the body (laterally to the nerve cords and dorsally to the intestine), but also the medial region behind the copulatory organs.

At the level of the genital atrium the oviducts turn inwards and slightly posteriorly, and unite behind the atrium, one of them passing below the stalk of the bursa copulatrix. The common oviduct thus formed runs ventrally and opens into the posterior part of the male atrium at the point where it passes over into the canal leading to the genital pore. Heavily stained eosinophilic glands empty into the dorsal two-thirds of the common oviduct and into short adjacent parts of the separate oviducts. The glands themselves lie in the surrounding parenchyma, chiefly above and behind the copulatory apparatus.

The genital atrium (Figs. 21 and 22) is relatively small and consists almost exclusively of a male atrium. A well-defined common atrium is absent and the stalk of the bursa branches off from the atrial complex very close to the genital pore. The male atrium is almost entirely occupied by the penis and repeats the shape of it. Posteriorly it tapers and connects with the genital pore through a short narrow passage, which receives the common oviduct as well. The atrium is lined by a cubical or flattened epithelium. Under this a layer of circular, and another one of longitudinal muscle fibers, are present.

The penis (Figs. 21-23) is composed of a relatively small bulb with feeble musculature and of the papilla or penis itself protruding into the atrium. The bulb is marked off from the surrounding parenchyma by a somewhat denser texture of muscle fibers, its internal portion consisting chiefly of parenchymatic tissue.

In the preparations the penis itself appears to be rather variable in shape and size. This is partially due to the different degree of maturity in the animals, partially to the different state of contraction in the fixing fluid; besides this, certain constant differences seem to exist between specimens from different localities. In general the penis is either cone-shaped or hemi-spherically rounded, sometimes gland-shaped with a constriction at the base, or it may show transitional forms. The base of the penis is coated with a ring of thickened epithelium consisting of long columnar cells of varying height, from 25 to  $140\mu$ . These cells often protrude into the atrial cavity as villus-like projections. A strong sphincter is present under the epithelium; this, by its contraction, causes the gland-like constriction of the base. The remaining part of the papilla has a cubical or flattened epithelium and a weaker layer of circular muscle fibers. Further inside, longitudinal muscles are present in both the proximal and distal parts of the penis papilla. Near the point of the papilla a peculiar muscular differentiation is developed, generally showing a wart-like appearance, more rarely a finger-like shape; it may

be more or less marked off from the rest of the papilla. It may be situated exactly at the point of the penis (Fig. 21), or lie excentrically, usually more towards the right side. It is covered by an exceedingly thin epithelium and contains a powerful musculature composed chiefly of longitudinal and dorso-ventral fibers.

Numerous outlets of glands open on the surface of the penis. The glands proper are situated far away in the general parenchyma surrounding the penis bulb, particularly to its anterior and lateral sides. The outlets penetrate the bulb and penis and empty through the epithelium. Only the thick ring of cells at the base of the penis, the muscular wart near the end, and a narrow strip of epithelium running from the wart to the base are free from gland openings. The secretion is granular and appears in a red to lilac shade after staining with hematoxylin and erythrosin.

The tubular ejaculatory duct passes through the bulb and the papilla; it is an almost cylindrical canal, slightly tapering posteriorly and often curved in winding loops. On its anterior end the two vasa deferentia open into it independently of each other. Sometimes two insignificant enlargements of the ejaculatory duct are developed to receive them. The duct opens posteriorly on the ventral surface of the penis, often rather close to its base. The lining epithelium is flattened and is coated by a distinct layer of circular muscles. The duct also seems to receive a granular secretion of pink color. No distinct seminal vesicle is present.

The bursa copulatrix is a rounded or more or less compressed, often lobate sac of varying size, according to the state of maturity of the animal. Its outlet, the stalk, proceeds to one side of the median line, usually to the left side, but occasionally to the right. Its epithelium is columnar to cubical and surrounded by a well-developed coat of muscle fibers arranged in two layers, an inner circular and an outer longitudinal one. The stalk may be differentiated into two portions, a wider and more muscular posterior one, which opens close to the genital pore, and a narrower anterior portion connected with the bursa and provided with a thinner muscular coat. The boundary between these two portions is fairly distinct in several cases (Fig. 21), so one is tempted to call the posterior part a "vagina," as we do similar structures in other planarians. On the other hand, there may be merely a gradual tapering towards the bursa without any abrupt change in the thickness of the wall (Fig. 22). Also intermediate conditions between the two extremes occur rather frequently. Specimens from the same locality generally show a uniform structure of the bursa stalk.

No adenodactyl is present.

In view of the wide variability in the copulatory apparatus, it appears to be possible to distinguish at least two different forms, which may represent two taxonomical units. However, the existence of specimens showing transitional characteristics seems to contradict this assumption. Specimens from the vicinity of Mountain Lake and from Camp Kewanee agree in a number of features: the glands of the penis are exceedingly well developed, the muscular wart situated eccentrically towards the right side of the penis, the ejaculatory duct opens farther distally, the stalk of the bursa lacks differentiation into two distinct regions. Since these specimens live in localities at high altitudes (about 4000 feet), they might be considered ecological varieties. Their peculiarities, however, remain constant even if they are kept under laboratory conditions for a long time. Nevertheless, for the reasons mentioned, I refrain from designating them as a distinct variety or subspecies.

**ECOLOGY AND DISTRIBUTION:** *Fonticola morgani* lives preferably in running water, particularly in places where the temperature is not very high during the summer. It occurs on the lower surfaces of stones in creeks and springs, rarer in spring-fed ponds. It may also be found in small, and even very small, springs that dry up periodically; from this fact we may conclude that it may also live in subterranean habitats, in the ground water, as is very probable in the case of several European spring planarians.

#### Distribution in Virginia:

(1) "Dog Spring," about  $2\frac{1}{2}$  miles southwest from the University of Virginia, Albemarle County. Small creek on David Fowler's Farm, by the old Lynchburg Road. Bottom muddy with little vegetation. September 8, 1931 (water temperature  $17^{\circ}\text{C}.$ ): several small immature specimens found in samples of mud and water plants brought to the laboratory. The white triclad used by Kepner and Rich (1915 and 1918) for experimental purposes and in their papers called "*Planaria albissima*," had been collected in the same place. Beauchamp (1932, p. 273) appears to assume Kepner's form to be identical with *Fonticola velata* (Stringer); this is obviously a slip, since *velata* is a pigmented species.

(2) Tributary of Ivy Creek, near Charlottesville, Albemarle County. Creek crossed on Garth Road about one-half mile beyond entrance to Farmington Country Club. Swiftly running, clean water; bottom covered with pebbles, muddy here and there, without vegetation. January 1 (water temperature  $11.7^{\circ}\text{C}.$ ) and January 31, 1932 ( $5.3^{\circ}\text{C}.$ ): numerous immature animals collected.

(3) Chamberlain's Pond, near Charlottesville, Albemarle County. Spring-fed pond on Midmont Estate, about one-half mile from the University of Virginia. Bottom muddy, covered with many dead leaves. April 6, 1932: several immature specimens brought to the laboratory in samples of mud and leaves.

(4) Creek near Stony Point, about 6 miles from Charlottesville, Albemarle County. Small creek, swiftly running; bottom mud and stones. May 8, 1932: several immature animals collected under stones (coll. Miss Ada A. Blanco).

(5) Creek near Greenwood, Albemarle County. Creek "Stony Run" at the place called Woodland, about one-half mile from Greenwood Station. May 15, 1932: numerous specimens, some of them mature, collected under stones.

(6) Lickinghole Creek, near Crozet, Albemarle County. May 15, 1932: mature and immature specimens.

(7) Spring at Afton Mountain, Nelson County. Small spring on the right side of the highway Afton—Waynesboro, about one mile before the crest of the saddle. During the summer the spring dries up. August 31, 1931 (water temperature 16°C.) and May 1, 1932: several small and immature specimens.

(8) Creek near Waynesboro, Augusta County. Creek on the western slope of the Afton Mountain, on the left side of the highway Afton—Waynesboro, flows into the South River at Waynesboro. Clear, swiftly running water, bottom with mud and stones. May 29, 1932 (water temperature 15.1°C.): numerous specimens, among them several mature ones, collected under stones. Some animals appear to have undergone fission: short postpharyngeal regions, re-generating tail-ends.

(9) Whiskey Creek, near Churchville, Augusta County. Swiftly running water. June 15, 1932 (water temperature 20.9°C.): several immature specimens under stones.

(10) Buffalo Branch near Buffalo Gap, Augusta County. Small, sluggish stream; bottom with stones, without vegetation. June 21, 1932 (water temperature 21.1°C.): a few immature specimens collected.

(11) Springs near Mountain Lake, Giles County. (a) Small spring on the east side of the lake; it is cased and feeds the water supply of Hotel Mountain Lake. The overflow of the reservoir is an iron pipe, from which the water falls into a small pond with a sandy bottom and many decayed leaves in it. In this pond the animals were very numerous (November, 1931), particularly attached to the leaves, but also gliding freely over the bottom. The crowding of the animals appeared to be due to their positive rheotaxis: the animals, moving against the current, were forced to stay in the pond and so collected there in great numbers. September 2, 1931 (coll. Mrs. Jeanette S. Carter), November 23, 1931, June 26, and July 5, 1933: Numerous specimens, some of them mature. (b) Creeks and springs on the way from Mountain Lake to the Cascades: "Skunk Cabin Spring", "Lary's Waterloo". June 29, 1933. (c) Bear Cliff Spring, northeast of Mountain Lake. June 30, 1933: several specimens under stones. (d) Small spring on the west bank of Mountain Lake. July 13, 1933: numerous immature specimens. (e) Spring on the north side of the lake, near the place where the carriage road proceeding along the east bank starts. Spring almost dry, somewhat marshy, with many dead leaves. November 23, 1931: one immature specimen. (f) Small spring on the east slope of Salt Pond Mountain, southeast of Mountain Lake, tributary of Johns Creek. Cold, clear water, muddy bottom with stones. July 16, 1933: one mature and several immature specimens. (g) Johns Creek, upper part, east of Mountain Lake. Clear, cold water. July 16, 1933: one immature specimen.

(12) Mountain Lake, Giles County. On the east bank of the lake, near the pump. June 27, 1933: several specimens under stones.

(13) Spring on the road Newport-Mountain Lake, Giles County. About 5½ miles from Newport, at an altitude of approximately 3500 feet. April 18, 1932: several specimens (coll. Dr. Paul R. Burch).

(14) Creek about 2 miles from Newport, Giles County, on the road Newport-Mountain Lake. August 8, 1932: numerous immature animals collected under stones.

(15) Spring near Camp Kewanzee, Apple Orchard Mountain, 17 miles from Bedford, Bedford County. Small creek and marshy spring near the camp. Water cool and clean. November 22, 1931: several specimens, one of them mature, collected under stones.

(16) Cave Spring near Lexington, Rockbridge County. Creek springing from a small cave close to the North River, northwest from Lexington. Water cool and clear. May 16, 1932: one immature specimen found under a stone after long searching.

(17) Miller's Spring near Kerr's Creek, Rockbridge County. Spring near the highway Lexington-Rockbridge Baths, about 9 miles northwest from Lexington. Swiftly running, cool and clean water, bottom with stones. May 16, 1932: a few immature specimens among numerous *Fonticola morgani* var. *polycelis* collected.

(18) Spring near Amsterdam, Botetourt County. Spring on Frank Preston Farm, about 16 miles from Roanoke. April 22, 1932: several immature specimens collected on a piece of wood lying in the stream.

(19) Spring near Endless Caverns, Rockingham County. The same locality as that where *Fonticola gracilis* was collected. June 24, 1932: A few immature specimens collected under stones.

(20) Blue Spring in the Gorge on the Bullpasture River, between Clovercreek and Williamsville, about 10 miles from McDowell, Highland County. Swiftly running, clean, cool creek, bottom with stones. June 6, 1932 (water temperature 11.1°C.): one immature specimen.

(21) Spring 3 miles from Hot Springs, Bath County. Spring beyond the Cascades at Cascades Inn. September 11, 1932: several immature specimens (coll. Miss Ada A. Blanco).

(22) Crabtree Falls, northwest from Lovingston, Nelson County. Swiftly running, clear creek, not very cool. June 5, 1932: several immature specimens collected under stones.

(23) Little Falls Stream, on the old "King's Highway", near Fredericksburg. May 5, 1933 (coll. Dr. Wm. A. Kepner).

**REPRODUCTION:** In nature one mostly finds only small and immature animals; mature ones may be collected particularly in cool springs and, during the spring, also in creeks. Occasionally one observes signs of recent asexual reproduction, such as an area of regenerating tissue at the posterior end, and a posterior position of the pharynx. From these facts I conclude that reproduction takes place chiefly in an asexual way. In the laboratory, however, I always succeeded in inducing the formation of sex organs by keeping the cultures at low temperatures (10-12°C.) and feeding them well. At indoor temperatures the cultures survived but a short time; the animals, in this case, showed a tendency to break up at different levels of the body. The pieces, kept under favorable conditions, occasionally gave rise to new individuals; nevertheless, the

whole process gave an impression of a pathological division rather than of a normal fission.

In view of the fact that sexual organs develop at low temperatures, we may assume that the type of propagation in natural surroundings is controlled chiefly by this factor. Low temperatures may induce sexual reproduction, high temperatures may bring about asexual fission. In springs and creeks with varying temperatures the animals will lay cocoons during the cold season and propagate asexually during the summer. In cool springs, where the temperature is almost constant all the year round, and in creeks at relatively high altitudes, the period of sexual activity may be longer.

Under laboratory conditions, mature animals frequently deposit egg capsules. During the formation of the capsule in the genital atrium an aggregation of cell material in this region may even show externally. Later on the cocoon assumes a reddish brown color and shows through the body wall. After deposition, the cocoon darkens and becomes darkly brown. It is unstalked, spherical or elliptical, its longer diameter on an average amounting to about 1.5 mm., its shorter diameter to somewhat less. Maximum dimensions 1.95 x 1.77 mm., minimum size 1.23 x 1.02 mm., respectively.

A cocoon that I opened contained 14 embryos.

TAXONOMIC POSITION: *Fonticola morgani* is apparently closely related to the typical representatives of the genus *Fonticola* and has also been classed with this genus by Hyman (1931b, p. 328). It differs, however, from the forms so far comprised in this genus, the typical species of which is *F. olivacea* (O. Schmidt). In these species the zone of the testes extends backwards almost to the posterior end, while in *F. morgani*, the testes are situated only anteriorly to the copulatory organs. Hyman has already pointed out this peculiarity.

I am inclined to consider these features as characteristic of a natural group of species; this seems to be confirmed by a narrower geographical distribution of the group. In any case, the forms of this group represent a link between the genera *Fonticola*, which they resemble most closely, and *Polyclelis*, from which they differ by the number of eyes. In order to include them with the genus *Fonticola*, the definition of this genus would have to be extended. Indeed, the posterior limit of the zone of testes does not appear significant enough to establish a new genus on the base of it alone, since the other anatomical features in no way decline from the general plan characteristic of the typical species of the genus *Fonticola*. I therefore adopt Hyman's (1931b, p. 328) proposi-

tion to change the definition of this genus, so that it would read as follows:

Genus *Fonticola* Komárek: *Planariidae* whose oviducts—without embracing the stalk of the bursa copulatrix—unite in a common oviduct which opens into the genital atrium. Male atrium without radial muscle plates. Adenodactyls absent. Eyes usually two (exception: *F. morgani* var. *polycelis*). Type of the genus: *F. olivacea* (O. Schmidt).

***Fonticola morgani* var. *polycelis*, n. var.**

**GENERAL FEATURES** (Figs. 7, 12, 18): This variety differs from the type by the number and the arrangement of the eyes. The type, as already described, has two principal eyes, and occasionally single secondary eyes as well. In the variety *polycelis*, however, the number of eyes is very large. The other anatomical features are the same in both forms.

The eyes are arranged in two bands, lying close together, one on each side of the median line, and extending parallel or slightly converging anteriorly. Within each band the eyes are distributed irregularly, not arranged exactly in one row. The length of the bands varies somewhat in specimens from different localities, but is fairly constant for each locality. The posterior end of the bands is at about the level of the anterior end of the anterior intestinal ramus; anteriorly, the limit is not so constant: in specimens from Waynesboro the bands occupy about one-fourth to one-half of the length of the pre-intestinal region of the body, in animals from Miller's Spring about two-thirds and in those from Big Spring three-fourths or even more of that length.

The number of eyes varies considerably. In general, young (small) specimens possess fewer eyes than old (big) ones. In specimens of different size, both mature and immature, all collected in Big Spring, I counted the numbers shown in Table 1.

Only exceptionally the number is the same on both sides. Sometimes the eyes are arranged so densely that it is difficult to count them. The eyes are of different sizes (see Fig. 18): besides large or I may say "normally" developed eyes, smaller or larger spots of eye pigment occur. It appears doubtful as to whether these spots actually represent functioning eyes. I am inclined to attribute an optical function only to the larger eyes of typical shape.

In this variety it can be observed that the eye pigment is being constantly renewed. In whole mounts one sees clots and granules of pigment lying in the parenchyma between the eyes and apparently being eliminated from them. These presumably pass backward towards

the branches of the intestine and enter the digestive epithelium. The anterior branches usually contain a large number of dark granules which by their size and color prove to be eye pigment (Fig. 18).

Similar phenomena have been observed in *Dendrocoelum album* (= *Polycladodes alba*; see Kenk, 1926, p. 179) and in other species. It seems that, generally, the eye pigment in planarians is either constantly or periodically renewed (cf. Ghisalberti, 1919) and the old one eliminated (or digested?) by the intestine.

**ECOLOGY AND DISTRIBUTION:** The variety *polycelis* occurs in localities similar to those where the type of the species is found. It is, however, rarer than the type.

TABLE 1

LENGTH OF THE PRESERVED ANIMAL mm.	NUMBER OF SPECIMENS	NUMBER OF EYES			
		Minimum on one side	Maximum on one side	On both sides	Average on both sides
1-2	11	3	29	7-49	19.1
2-3	10	11	34	23-65	41.7
3-4	7	13	45	29-83	50.0
4-5	9	17	67	35-126	65.9
5-6	1	25	27	52	52
6-7	1	36	39	75	75
Among them 5 mature animals, 4-7 mm. long.....	5	20	66	44-126	69.8

#### Distribution in Virginia:

(1) Big Spring, near Kerr's Creek, Rockbridge County. The same locality as that where *Euplanaria tigrina* was collected. Enormous numbers of specimens on the lower surface of stones in the springs themselves and in adjacent parts of the pond. September 11 (water temperature 15°C.) and October 11, 1931 (15.2°C., pH 7.2), May 16 and 22, 1932: mature and immature specimens.

(2) Miller's Spring, near Kerr's Creek, Rockbridge County. The same locality as that where the typical *Fonticola morgani* was collected. May 16, 1932: numerous mature and immature specimens under stones.

(3) Creek near Waynesboro, Augusta County. The same locality as that where *Curtisia foremani* was collected. March 26 and April 3, 1932: numerous mature and immature specimens collected under stones.

**TAXONOMY:** According to the exact wording of the definition of the genus *Polycelis* (Kenk, 1930b, p. 294) *Fonticola morgani* var. *polycelis* ought to be classed with this genus. On the other hand, the perfect conformity with the typical *Fonticola morgani* as regards the anatomical

structure, as well as the existence of transitional forms, excludes any doubt of the close relationship to the latter species.

This case clearly shows that the number of eyes in planarians is of secondary significance as a generic characteristic and that it ought to be avoided in generic definitions, whenever possible. It appears necessary to distinguish the genus *Polycelis* from related genera by more accurate features. This, however, can be done only after an extensive comparative study of the species ranking in this genus.

Typical locality of *Fonticola morgani* var. *polycelis*: Big Spring near Kerr's Creek, Rockbridge County.

**Planaria dactyligera, n. sp.**

**EXTERNAL FEATURES:** Sexually mature specimens attain a length of 13 mm. and measure about 1.75 mm. across the widest part. The dorsal surface is darkly pigmented; the color may vary from almost black to a dark brown or gray. The ventral surface is somewhat lighter than the dorsal, usually gray. The pigment is almost uniformly distributed, without showing definite spots or stripes, at most a faintly clouded effect. Only a small area above each eye is free from pigment and frequently the situation of the copulatory organs (particularly of the adenodactyl) may be marked by a slightly lighter pigmentation of the dorsal surface above them.

The general shape of the animal, when gliding along undisturbed, is shown in Figures 5 and 13. The anterior outline is truncated. During locomotion the front margin of the head is subject to slight modification, the median part occasionally projecting a little. The lateral edges of the head are rounded, forming obtuse auricular projections. Behind these a very insignificant incurving may be observed in gliding animals. Then the body increases to the zone of maximum width and after that tapers gradually to the rather pointed posterior end.

*Planaria dactyligera* has normally two eyes, placed relatively far behind the anterior end; their distance from each other amounts to about one-third of the body width at the eye level, while their distance from the front end is a little less than the body width.

The basis of the pharynx lies near the middle of the body and the pharynx covers approximately one-third of the length of the posterior half of the body. The second third is occupied by the copulatory apparatus.

**STRUCTURE OF THE SKIN:** The structure of the surface epithelium shows no peculiarities.

The body pigment appears to consist of brownish black pigment

granules enclosed in ramified cells of the parenchyma. These are situated close to the surface epithelium, between the fibers of the external body musculature and penetrating but little towards the deeper layers (only as far as the layer of the rhabdite-forming cells).

On the ventral side of the head there are numerous openings of gland cells. They cover an elongated area along the median line behind the zone of the marginal adhesive cells. Their secretion is slightly eosinophilic. I have not been able to establish any particular differentiation in the muscular layers in this part. Nevertheless, this area presumably represents a primitive adhesive organ, such as is not uncommon among the tricladids. Characteristic of the marginal epithelium just referred to is the depressed position of, at least, the greater number of the nuclei.

**DIGESTIVE SYSTEM:** The structure of the pharynx exhibits the arrangement typical for the family *Planariidae*: the circular and longitudinal fibers of the inner muscular zone form distinct layers. The outer muscular zone lacks a second (inner) layer of longitudinal fibers.

The branching of the intestine cannot easily be studied in living specimens because of the dark pigmentation of the body. In longitudinal sections I counted 6 to 7 lateral branches on the anterior ramus.

**SENSE ORGANS:** There are usually two eyes. Single supernumerary eyes may occur, but are smaller than the "principal eyes." The retina consists of a fairly large number (at least 15-20) of optical elements.

The head is provided with a pair of strips of modified surface epithelium, which I consider to be auricular sense organs. These lie along the frontal margin on each side, between the edge of the head and the submarginal adhesive zone. Their cells contain only few rhabdites and the nuclei occupy a normal position (in other species, the auricular sense organs frequently show depressed nuclei).

**REPRODUCTIVE SYSTEM (Figs. 25 and 27):** The numerous testes may be rounded or polygonal and occupy the ventral part of the body. Only occasionally some of them rise towards the dorsal side. They form a broad band on each side of the anterior ramus of the intestine and of the pharyngeal pocket, respectively. Each band is stretched above the ventral nerve cord of that side, overlapping it both medially and laterally. It extends from a short distance behind the ovary to about the level of the mouth. In a transverse section, from 3 to 5 testes may show in each band.

In the anterior half of the body, the vasa deferentia are narrow ducts with thin walls. They are not quite straight and follow the line of the ventral nerve cords on their medial sides, not closely attached to them

and also slightly removed from the ventral body musculature. They are connected with the testes by extremely fine tubules (*vasa efferentia*) which are longer or shorter, according to the distance of the testis from the *vas deferens*. Some testicular follicles open directly into the latter. The *vasa efferentia* of the testes situated on the outer side of the ventral nerve pass over the nerve cord to reach the *vas deferens*.

In the region of the pharynx, the *vasa efferentia* expand into large tubes filled with sperm (false seminal vesicles). They proceed in a winding course to the penis bulb and enter it, usually asymmetrically (the one more dorsally than the other). After a few more loops within the bulb they open united, or at least close to each other, into the seminal vesicle.

The ovaries (germaries) are in the normal position behind the cerebral commissure and medial to the ventral nerve cords. On their lateral and dorsal sides there are lobate masses of cells closely packed together. These may represent "parovaries" such as occur in many planarians. They consist partially of undifferentiated cells with darkly stained plasma, partially they are clearly differentiated into yolk cells. It has been repeatedly assumed that parovaria and yolk glands are related organs. This is confirmed once more by the structure of the parovary in our species.

The oviduct starts from the lateral part of each ovary and proceeds caudally above the ventral nerve cord, with yolk glands attached to the greater part of it. At the level of the copulatory organs it turns inward and dorsally, and unites with the oviduct of the other side, the left one passing between the bursa stalk and the wall of the genital atrium. Then the common oviduct descends ventrally and more or less caudally to open into the posterior part of the "male" atrium. The terminal parts of the separate oviducts and the upper two-thirds of the common oviduct are both connected with shell glands.

The genital atrium (Fig. 27) is small and almost entirely limited to the male atrium fitting the shape of the penis. A well-defined common atrium is absent, since the bursa stalk and the adenodactyl open almost independently through the genital pore. The atrium is lined with a cubical ciliated epithelium. Under it there is a layer of circular muscles and beyond that one of longitudinal muscles.

The penis consists of a relatively well developed bulb and a pointed cone-shaped papilla. The musculature of the bulb forms concentric layers of fibers, particularly in its peripheric parts. The bulb contains the curved ends of the *vasa efferentia* and the seminal vesicle. The

papilla or penis itself is covered by a flattened epithelium. The wall is provided with two layers of muscle fibers, a circular and a longitudinal one. The seminal vesicle merges into the ejaculatory duct without a definite boundary. The latter proceeds straight to the end of the penis, tapering gradually towards the point. The epithelium of the vesicle and of the anterior part of the duct is thick, but gradually flattens posteriorly. It is penetrated by numerous gland ducts containing a granular, faintly eosinophilic secretion. The gland cells to which these ducts belong, are situated outside the penis in the parenchyma surrounding the penis bulb.

The bursa copulatrix is a voluminous sac, lying immediately in front of the penis bulb. Its structure does not decline from the usual norm. The rather narrow bursa stalk proceeds slightly to the left side of the mid-line. It does not present any definite regions such as are found in several other planarians. Its lumen is lined by a very thick epithelium with villus-like projections. These probably perform a glandular function. Externally the stalk is coated with two layers of muscle fibers: circular fibers immediately under the epithelium, longitudinal muscles outside the former.

**Adenodactyl:** Particularly interesting is the presence of a well-developed adenodactyl or muscular gland organ. In a recent paper, Hyman (1931a, p. 126) calls attention to the fact that none of the North American species known so far possesses adenodactyls. Our species is, therefore, easily recognizable by this organ.

The adenodactyl is a highly muscular, ovoid organ situated behind the atrium, its longer axis extending obliquely from posterodorsal to anteroventral. Its musculature consists chiefly of circular fibers. The lumen is quadrangular in cross section and opens through the point of a small projection (papilla) into the atrium immediately near the genital pore. When the animal is fully mature, this cavity is entirely filled with glandular secretion which in the preparations appears darkly stained (blue or violet after staining with hematoxylin and eosin). In younger specimens a cubical ciliated epithelium is seen lining the cavity. The glands emptying into it lie in the parenchyma and their outlets penetrate the muscular layer as well as the inner epithelium. The whole organ is connected with the ventral body wall by single muscle fibers; these evidently perform the rôle of protractors. The function of this organ as well as of similar organs in other tricladids is still doubtful.

**ECOLOGY AND DISTRIBUTION:** *Planaria dactyliigera* occurs in cold water springs and in spring-fed ponds. It may be found on the lower

surfaces of stones or among water plants. Sometimes it is seen moving over the bottom of a pond even in the day-time.

Distribution in Virginia:

(1) Big Spring, near Kerr's Creek, Rockbridge County, i.e. the same locality where *Fonticola morgani* var. *polycelis* and *Euplanaria tigrina* were collected. In the springs, its occurrence among *F. morgani* var. *polycelis* is comparatively rare, but at a short distance from the springs, in the pond itself, it markedly predominates. September 11 and October 11, 1931, March 2 (coll. Dr. William A. Kepner), May 16 and 22, 1932: both young and sexually mature specimens collected. Egg capsules were brought into the laboratory with samples of mud and water plants.

(2) Mountain Lake, Giles County. (a) South bank, at the fish pool, below Mountain Lake Hotel. August, 1931 (coll. Mrs. Jeanette S. Carter). (b) East bank, near the pump. June 27 and July 13, 1933: numerous specimens under stones. (c) North bank, near the boat house. July 7 and 13, 1933: under stones.

(3) Pond on the left bank of Bullpasture River, about 5 miles below McDowell, Highland County. Small spring-fed pond with rich vegetation, ground swampy. June 6, 1932: several specimens brought into the laboratory in samples of mud (coll. Mr. C. M. Gilbert).

(4) Swamp near Rio, about 3 miles from Charlottesville, Albemarle County. June 6, 1932: several specimens (coll. Mr. T. K. Ruebush).

**REPRODUCTION, DEVELOPMENT:** The species apparently occurs sexually mature during all seasons of the year. It may be kept in the laboratory for a long time, but seems to require clean water and low temperature. Four specimens raised in a refrigerator at 10–12°C. and well fed on beef liver, laid 34 egg capsules during the period from January 31 until August 15, when the culture had to be discontinued. However, the period of sexual activity seems to be exceedingly long in this species.

The cocoon is elliptical or—more rarely—spherical, and unstalked. The size varies considerably: the biggest cocoon I measured attained 1.46 mm. (long axis) x 0.99 mm. (short axis), the smallest 0.68 x 0.65, a small, almost spherical capsule measured 1.23 x 1.12 mm. The freshly laid cocoon is yellowish brown, but soon darkens and, after a few days, appears darkly reddish brown. It is attached to the substratum by a transparent colorless jellylike substance in which it is also embedded (see Fig. 19).

The number of embryos in one egg capsule is subject to wide variation, from one to eight. This fact suggested dependence of the number of embryos on the dimensions of the egg capsule, especially upon its volume. Therefore I measured 28 cocoons collected in the field (Big Spring, October 11, 1931) and calculated the volume. This may be

obtained without a serious mistake by using the formula for an ellipsoid: volume =  $\frac{\pi}{6} \times d^2 \times D$ ,  $d$  and  $D$  being respectively the short and the long axis of the egg capsule. The volume so established ranged from 0.150 to 0.807 mm<sup>3</sup>., an average of 0.417 mm<sup>3</sup>. From two of these cocoons, no animal hatched, from one of them, one animal hatched, leaving a voluminous mass of dead cell material in the capsule; these three cocoons I had to eliminate from the calculation. The remaining 25 cocoons showed an apparently normal development. The results are given in Table 2.

As far as we may judge from these scanty data the number of egg cells in a cocoon really seems to be to a certain degree in correlation with its size.

On the other hand, the quantity of yolk material apportioned to each egg cell may determine the size of the young animal. The more yolk at its disposal, the larger the embryo may grow within the egg capsule. Indeed, one observes considerable differences between hatching animals, their length varying from 1.28 to 3.8 mm.

TABLE 2

Volume of cocoons.....	0.150-0.399 mm <sup>3</sup> .	0.4-0.807 mm <sup>3</sup> .
Number of cocoons.....	11	14
Number of animals hatched.....	30	51
Average number of animals per cocoon...	2.73	3.64

When the animals leave the cocoon, they are without body pigment, entirely white; only the two small black eye spots are developed. During the following days they gradually become pigmented and exhibit a grayish or brownish appearance. The pigment formation is apparently controlled to a certain extent by the light: animals kept in the dark appeared markedly lighter than others of the same age raised in daylight (cf. Perkins, 1929, p. 759).

**TAXONOMY:** *Planaria dactyligera* differs from the species now comprised in the genus *Planaria* by only one important characteristic. The representatives of this genus, as defined in an earlier paper (1930b, p. 293), show the zone of testes extending almost to the posterior end; in the new species, however, testes are developed only anteriorly to the copulatory organs. On the other hand, the structure and position of the well-developed adenodactyl in the new species reveals, in my opinion, a true relationship with the genus *Planaria*. I therefore prefer to extend the definition of this genus, which would then be as follows:

Genus *Planaria* O. F. Müller: *Planariidae* whose oviducts—without embracing the stalk of the bursa copulatrix—unite in a common oviduct which opens into the genital atrium. Male atrium without radial muscle plates. Adenodactyl present, constructed according to the *Planaria torva* type. Type of the genus: *Pl. torva* (O. F. Müller).

Typical locality of *Planaria dactyliigera*: Big Spring, near Kerr's Creek, Rockbridge County, Virginia.

### *Procotyla typhlops*, n. sp.

The genus *Procotyla* was hitherto represented by one single species, viz., *Procotyla fluviatilis* Leidy. This species has been for a long time confused with the European *Dendrocoelum lacteum*, but is definitely different from the latter and marked by several peculiarities especially with regard to the male reproductive organs. An extensive account of its morphology and ecology was recently published by Hyman (1928). This paper also throws light on the rather puzzling rôle played by this species in the literature concerned; since now *Procotyla fluviatilis* ranks among the best known North American planarians. I shall have to refer repeatedly to Hyman's paper.

*Procotyla typhlops* resembles *Pr. fluviatilis* in many respects. It shows, however, several marked differences.

**EXTERNAL FEATURES:** Mature specimens, when fully distended, attain a length of 12 mm. and a greatest width of 1.33 mm. The species is considerably smaller and more slender than *Procotyla fluviatilis*.

The body lacks pigment and appears white in fasting animals. When the intestine is filled, its contents show through the body wall changing the general color of the animal to a reddish or brownish hue. Nevertheless, the head, the edge, the regions of the proboscis and of the copulatory apparatus remain milky white. There are no eye spots.

The anterior end (Figs. 8, 14) is truncate, the frontal margin running transversely, the middle part occasionally slightly protruding. On its ventral surface, a very faintly indicated adhesive organ may be discerned. I shall presently return to the structure of this organ. The lateral edges of the anterior margin are rounded, very slightly projecting laterally; so we may call them auricular appendages. Behind them a very slight constriction of the lateral margins may be observed. Then the body widens gradually and evenly to attain the greatest width only at about the middle of the body length. Behind the level of the copulatory organs the margins converge. The posterior end appears sometimes pointed, sometimes rather blunt while the animal is in motion.

The root of the pharynx is situated at about the middle of the body or

somewhat posteriorly to it. The copulatory organs in fully mature specimens occupy about two-thirds of the postpharyngeal region.

THE SURFACE EPITHELIUM is formed on the usual plan. I want to discuss only a few peculiarities of the body margin and the anterior end. The epithelium of the margin is taller and its cells are densely filled with rhabdites, which also appear taller than those from other regions of the surface; similar conditions have been found in *Procotyla fluviatilis*. The usual zone of adhesive cells is situated below the edge of the margin. It consists of a strip of "depressed" epithelium destitute of rhabdites and perforated by numerous outlets of eosinophilic glands. In most of the fresh-water planarians this strip forms a continuous border along the entire margin of the body. In our species, however the adhesive strip, slightly widening towards the anterior end, is interrupted in two spots symmetrically placed one on either side of the ventral surface of the head. Identical conditions are reported by Wilhelm (1909, p. 158) to occur in marine triclad. The short middle portion of the adhesive zone, disconnected from the lateral and posterior part, represents a primitive adhesive area. It is comparatively broad, but as far as its structure is concerned, it is the same as the main adhesive strip. I have not succeeded in discovering any modification of the muscular layers of the body wall in this place. Presumably, its function is to adhere to the substratum by means of its sticky secretion. It may be used this way in crawling locomotion and also in the capturing of prey.

The other species of the genus *Procotyla*, *P. fluviatilis*, possesses a highly developed sucker instead of a simple adhesive area. This organ performs both a glandular and muscular function. Nevertheless, in this species also the adhesive strip presents interruptions on both sides of the sucker, similar to those in *P. typhlops*. This fact suggests that the highly complicated sucker or grasping organ of *P. fluviatilis* evolved from a definite part of the marginal adhesive zone by gradual differentiation of the glandular structures and by a local modification of the muscular systems in its vicinity, particularly of the longitudinal muscle layer of the ventral body wall. The different structure of the adhesive organ in these two, very closely related, species shows that even well-developed suckers may be quoted for taxonomic conclusions only upon careful consideration. It is already well known that in different species of planarians all transitional stages occur, from primitive glandular areas to definite muscular adhesive organs.

DIGESTIVE SYSTEM: The pharynx is rather short, amounting to about one-tenth of the entire length of the body. It is built on the plan charac-

teristic of the family *Dendrocoelidae*: The inner muscular zone consists of intermingled layers of circular and longitudinal muscle fibers. Its external muscle zone consists of only two layers, a longitudinal and a circular one; a second, incomplete, layer of longitudinal muscles, such as is developed in several other *Dendrocoelidae*, is absent. The mouth is situated at the posterior end of the pharyngeal chamber.

The intestine presents the usual three main rami. Frequently the two posterior rami unite behind the copulatory organs, and form a median posterior ramus. On the other hand, they may be entirely separate. The number of lateral branches is subject to some variation: On the anterior ramus, there are 10-12, on each posterior ramus 15-21 lateral branches. The formula of the branching is, therefore: 15-21, 2(10-12), 15-21.

**SENSE ORGANS:** All traces of eyes are absent, as has been mentioned before.

The auricular sense organs cannot be seen in living animals. In microscopic preparations, however, I have observed structures at the anterior end which I believe to be such organs. There is one marginal strip of modified surface epithelium on each side of the median line, situated approximately above the place where the submarginal adhesive zone is incomplete. The epithelium there is of the normal structure (the nuclei not being depressed below the basement membrane), but lacking rhabdites and provided with very well developed cilia. These strips occupy exactly the edge of the body, to some extent encroaching upon the dorsal and ventral surfaces. At their lateral ends they border on the tall marginal epithelium, with numerous rhabdites, while that part of the frontal margin that lies between their medial ends is coated with a cuboidal epithelium.

**REPRODUCTIVE ORGANS** (Figs. 26, 28): The testes are numerous, situated mostly dorsally, only a few approaching the ventral body wall. They form a rather narrow zone above the ventral nerve cord on each side of the body. This zone begins a short distance behind the ovary and extends posteriorly to the region of the pharynx.

From each testis a very fine vas efferens leads into the longitudinal vas deferens. The latter is a narrow thin-walled canal passing close to the dorsal side of each ventral nerve cord, slightly medially to the oviduct. At the level of the pharynx the vas deferens moves a little medially and abruptly expands into a rounded sac lined with a thin but distinct epithelium. This enlargement is filled with sperm and represents a "false seminal vesicle." A thin coiled tube runs from it back-

wards to the level of the penis bulb, turns to the mid-line and unites with the tube of the opposite side. The common vas deferens or seminal duct then expands again, swollen with sperm, and forms several loops below the anterior part of the penis bulb and in front of it. Physiologically, this enlarged part performs the same function as the false seminal vesicle. The tube finally narrows again and enters the penis bulb at its anterior end.

The ovaries and oviducts present the usual structure and position: The ovaries are situated on the medial side of the nerve cords. The oviducts start from their lateral part with an enlarged section filled with spermatozoa: the seminal receptacle or tuba. Then they turn posteriorly and pass along the dorsal sides of the nerve cords, laterally to the vasa deferentia. They connect with yolk glands which abound in the parenchyma, lying both dorsally and ventrally to the intestine and between its lateral branches. Near the copulatory apparatus the oviducts turn inward and dorsally and unite in the space between the genital atrium and the stalk of the bursa copulatrix; the common oviduct thus formed proceeds ventrally and opens into the posterior part of the male atrium. Intensely stained eosinophilic glands (shell glands) empty into the upper part (about two-thirds) of the common oviduct as well as into a short adjoining portion (about  $80\mu$  long on each side) of the separate oviducts.

The genital atrium is relatively small and restricted almost entirely to the male atrium. This is conical in shape and contains the penis papilla or penis proper. Backwards it narrows into a short tube which proceeds posteriorly and on its dorsal side connects with the stalk of the bursa copulatrix. At the point of transition from the male atrium to the tube the common oviduct opens from above. After its juncture with the bursa stalk, the narrow atrial tube turns ventrally and ends at the genital pore. This short perpendicular part corresponds to a common atrium, but shows only a narrow lumen.

The epithelium of the male atrium appears rather flattened in the anterior section, near the basis of the penis; posteriorly it becomes cubical or even columnar. The cells there are of a very significant type, similar to those observed in *Procotyla fluviatilis* in the same place: the distal parts of the cells are closely packed with granules of glandular secretion which appear brilliantly red after staining with eosin or erythrosin; the basal portions of the cells lack such inclusions. The granules are formed by the epithelial cells themselves and are not emptied into them by external glands. No villus-like projections of the

epithelium, such as are described for *P. fluviatilis*, have been observed in this form.

The epithelium of the common atrium shows an entirely different structure. It is "depressed" and perforated by numerous outlets of eosinophilic glands which lie in the surrounding parenchyma.

The penis closely resembles this organ in *P. fluviatilis*. It consists of a relatively large bulb and of a small papilla or penis proper. The bulb is of elliptical shape and highly muscular. It contains a large cavity which is likewise elliptical and corresponds to a seminal vesicle. Its wall is formed by two muscular layers separated by a thin non-muscular layer. The external muscular layer, which is the thicker one, is composed of longitudinal muscle fibers running not exactly parallel to the main axis of the organ, but more or less obliquely from anterior and dorsal to posterior and ventral. The internal layer consists of circular fibers. The intermediate non-muscular stratum lacks distinct cell borders and nuclei. On closer observation one distinguishes minute fibers running in a circular direction and only very faintly susceptible to eosin. I call this stratum the fibrous layer. It is difficult to establish its exact histological structure. A similar structure may occasionally be found also in other species of planarians, e.g. in *Fonticola gracilis*, etc. Presumably it performs some mechanical function, as it appears to be both rigid and elastic.

In *Procotyla fluviatilis*, according to Hyman, the wall of the penis bulb consists of two longitudinal muscle layers separated by a mucous layer; the inner longitudinal layer corresponds to the circular layer of *Procotyla typhlops* and the mucous layer (the external mucous layer, as Hyman calls it) corresponds to our fibrous layer. This layer is more highly developed in *P. fluviatilis* than in *P. typhlops*.

The large cavity of the penis bulb is lined with a tall secretory epithelium, except for the posterior portion where the bulb merges into the papilla. The cells are club-shaped and almost entirely transformed into a faintly eosinophilic, finely granulated secretion which still shows the shape of the former cells. Unchanged protoplasm and nuclei remain only at the base of the epithelium, forming a thin and somewhat irregular lining. Similar masses of secretion occur in the lumen, but do not fill it entirely in my preparations. It is interesting that in *Procotyla fluviatilis* Hyman finds a free cavity only in young specimens, while in mature animals it is completely filled with mucus and thus appears solid throughout.

The penis papilla is conical, the posterior end often tapering off into

a finger-shaped and curved appendage. The wall is rather thin and includes a cavity which repeats the general shape of the papilla: anteriorly, where it passes over into the lumen of the bulb, it is wide, but gradually narrows posteriorly until it becomes a fine tube leading to the point of the papilla. The penis is coated with a flattened epithelium; immediately below this lies a fibrous layer which is continuous with the fibrous layer of the bulb; then follow longitudinal muscles continuous with the circular muscle layer of the bulb; and finally, the flattened epithelial lining which passes over into the secretory lining of the cavity.

The common vas deferens enters the penis bulb at its anterior part as a thin tube. It penetrates the muscular wall and proceeds posteriorly along the ventral mid-line of the organ, between the inner (circular) muscle layer and the epithelium lining the cavity. It is distended, filled with sperm, and projects slightly into the lumen. At the boundary between the bulb and the papilla it opens into the penis cavity. There is no special sphincter in this place. Hyman calls the corresponding tube in *Procotyla fluviatilis* the ejaculatory duct. In our case, where a distinct cavity is present, I prefer to call the canal a common vas deferens or seminal duct (Fig. 28, cvd) as it opens into the cavity. The ejaculatory duct is the short narrow lumen of the papilla. Morphologically considered, the cavity of the penis bulb corresponds to the seminal vesicle of other planarians; physiologically, however, it differs from this vesicle, since, most likely, it never contains any sperm. Its function is rather that of an accessory gland whose secretion is added to the sperm during the ejaculation. Woodworth (1897, p. 5) calls the corresponding structure in *Procotyla fluviatilis* the "prostate gland;" this name fairly indicates its actual function.

The bursa copulatrix is a voluminous sac of more or less varying shape. Its epithelium consists of big cubical cells provided with large secretory vacuoles. The outlet or stalk of the bursa starts from its posterior and dorsal part, runs posteriorly approximately above the penis, curves ventrally behind the male atrium and opens into the tube-shaped common atrium. The anterior part of the stalk is rather narrow and thin-walled, posteriorly it gradually widens and its epithelium becomes thicker; at the same time the thickness of its muscular coat increases. There is, however, no distinct boundary between the anterior and posterior parts of the stalk. The musculature consists of two layers: the circular muscles coating the epithelium and a layer of longitudinal fibers outside the former.

No adenodactyl or muscular gland organ is present.

**ECOLOGY AND DISTRIBUTION:** *Procotyla typhlops* has been collected in a cold limestone spring whose temperature seems to vary but little during the seasons of the year. It is found usually on the lower surface of stones. It is probable that the animal inhabits subterranean waters as well. The absence of eyes may be correlated with this habitat.

Distribution in Virginia:

(1) Big Spring near Kerr's Creek, Rockbridge County. In the same locality *Euplanaria tigrina* and other species were collected. *Procotyla typhlops* occurs in the springs themselves, but is rare in comparison with the other species. It also lives in the pond and one specimen was collected in the creek that is the outlet of the big pool. October 11, 1931, May 16 and 22, 1932: both young and mature animals collected.

**REPRODUCTION:** Sexually mature animals were collected in October and May. It is possible that the sexual organs develop during all

TABLE 3

PROCOTYLA TYPHOLOPS	P. FLUVIATILIS
Body length attaining 12 mm.	Body length attaining 20 mm.
Adhesive organ feebly developed, represented by a glandular area.	Adhesive organ a true sucker, provided with glandular and muscular differentiations.
Eyes absent.	Eyes present, 1 to 8 on each side of the head.
Muscles of the penis bulb form an external longitudinal and an internal circular layer.	The muscular wall of the penis bulb consists of two layers of longitudinal muscles.

seasons of the year, since the nature of the locality presents but little variation in temperature all the year round. I never have seen any indication of asexual reproduction. Asexual (probably young) animals attained maturity after having been kept at a low temperature (10-12° C.) for some time, often amounting to several months. No egg capsules were deposited in the aquaria.

**TAXONOMY:** From a comparison of the anatomy of the new species with the structure of *Procotyla fluviatilis*, as described by Hyman (1928), we see that these two species are very closely related. There is a striking resemblance, particularly in the structure of the reproductive organs. The most significant differences are shown in Table 3.

It is interesting to note that Beauchamp (1931, p. 320) recently expressed his opinion that a blind species of *Procotyla* might be discovered in America.

*Procotyla fluviatilis* has hitherto been the only species of the genus.

The characteristics of the new species *typhlops* render advisable a revision of the generic diagnosis that I have given in a former paper (1930 b, p. 296). The new diagnosis is as follows:

Genus *Procotyla* Leidy, 1857: *Dendrocoelidae* without adenodactyl; penis papilla present, penis bulb with two concentric muscular layers which are separated by a non-muscular layer. Oviducts unite in a common duct without embracing the stalk of the bursa copulatrix. Type of the genus: *P. fluviatilis* Leidy, 1857.

#### ECOLOGY AND DISTRIBUTION OF PLANARIANS IN VIRGINIA

Adopting the ecological classification of European planarians proposed by Steinmann (Steinmann und Bresslau, 1913, p. 151) and proved useful also in the case of other groups of aquatic animals, we may distinguish two groups of fresh-water tricladids in Virginia; viz. (1) those which prefer running water and are therefore to be found in springs, creeks, and rivers ("rheophilic" forms) and (2) others inhabiting, chiefly, stagnant water, such as ponds, pools, and lakes ("limnadophilic" forms). There is, of course, no sharp demarcation between these groups, just as there is no definite demarcation possible between running and stagnant water. Furthermore, we have to bear in mind that the reophily is not the only factor controlling the distribution of planarians. Other characteristics of the habitat likewise play an important rôle, such as the temperature and the chemical composition of the water, the kind and quantity of the food supply, and, perhaps less decisively, the nature of the substratum. The mutual competition between different species likewise comes into consideration. All these factors and perhaps a few more besides are apt to influence the distribution of water animals in a given area.

Returning to the question of rheophily we may characterize the species as follows:

##### Rheophilic forms:

- Fonticola morganii,*
- Procotyla typhlops,*
- Curtisia foremani,*
- Euplanaria dorotocephala.*

##### Limnadophilic form:

- Euplanaria tigrina.*

*Planaria dactyligera* and *Fonticola gracilis* occupy an intermediate position with regard to their habitats in Virginia.

As to the relations between the temperatures of the water and the occurrence of planarians, it has been known for a long time that certain species may live well within a considerably wide range of temperature. It is probable that for each species, perhaps even for different physiological races of a single species, a certain optimum temperature exists, in which growth and propagation attain the highest rate. Nevertheless, some species tolerate a marked deviation from the optimum without detriment. Such forms are eurythermic. Others are rather sensitive to abrupt changes in temperature, particularly to sudden rises: these are stenothermic.

Speaking generally, rheophilic species are stenothermic and prefer low temperatures, whereas the limnadophilic ones are eurythermic. My observations in the field and in the laboratory do not suffice to provide an exact classification of the planarians of Virginia from this point of view. In any case, some species proved to be markedly stenothermic, such as *Procotyla typhlops* and *Fonticola morgani*. *Euplanaria tigrina* and *Fonticola gracilis* are decidedly eurythermic.

Among certain rheophilic forms, there seems to exist a rule of distribution, similar to that found in the European species *Crenobia alpina*, *Polycelis felina* and *Euplanaria gonocephala*. These three species occur, usually, in a definite succession: *Crenobia alpina* inhabits the springs and the upper parts of mountain streams, at lower altitudes it is replaced by *Polycelis felina*, which, still lower down, gives place, in its turn, to *Euplanaria gonocephala*. In transitional zones both neighbouring species are found together. This particular distribution appears to be due chiefly to the temperature of the water in different parts of the stream. The spring exhibits a rather constant temperature all the year round, while in descending the daily and seasonal amplitudes of the temperature increase in rate. Temperature is not the only factor involved, but seems to be the principal one.

In a similar way, *Fonticola morgani* occurs in Virginia in the springs and upper reaches of creeks; in the lower parts it is accompanied or even supplanted by *Curtisia foremani* and *Euplanaria dorotocephala*. *Fonticola morgani* also proceeds farthest upwards in the mountains. I have, however, not carried out an intensive investigation of the distribution of these species in a limited area. Any conclusions regarding successive immigrations of the species concerned, such as have been shown probable in the case of European forms, would be premature because of the scarcity of data available at present. Only a detailed study of the distribution of the various species and a rational applica-

tion of the geological history of the country would justify a more definite opinion.

In two Virginian species, viz. *Procotyla typhlops* and *Fonticola morgani*, subterranean habitat is very probable, though not really established as yet. *Procotyla typhlops* is a blind species found in a spring near Lexington. The blindness as well as the limited distribution suggest that it lives in subterranean waters of this limestone region. *Fonticola morgani* sometimes occurs in very small springs which dry up in the summer. It probably retires to the ground water during the dry season. In the few limestone caves in the Shenandoah Valley which I visited, I did not, however, collect any planarians.

#### SUMMARY

(1) In Virginia seven species and one variety of freshwater trichads were collected.

(2) The forms investigated are:

*Curtisia foremani* (Girard)  
*Euplanaria tigrina* (Girard), syn. *Planaria maculata* Leidy.  
*Euplanaria dorotocephala* (Woodworth)  
*Fonticola gracilis* (Haldeman)  
*Fonticola morgani* (Stevens and Boring)  
*Fonticola morgani* var. *polycelis* n. var.  
*Planaria dactyligera* n. sp.  
*Procotyla typhlops* n. sp.

(3) Descriptions of the new forms are given and data concerning the old ones supplemented.

(4) The Virginian planarians are classified with regard to their ecology.

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## EXPLANATION OF FIGURES

Figs. 1-8. Photographs of living animals taken by the method described in Science, n.s. 75: 669-670. 1932.

Fig. 1. *Curtisia foremani* from Charlottesville, Va.,  $\times 6.6$ .  
 Fig. 2. *Eplanaria tigrina*. (a) From Sinclair's Pond, Charlottesville, Va.,  $\times 4.2$ . (b) From Big Spring near Kerr's Creek, Va.,  $\times 8.5$ . (c) From Park Spring Lake, Caswell County, N. C. (coll. Dr. Wm. A. Kepner),  $\times 5.3$ .  
 Fig. 3. *Eplanaria dorotocephala* from Big Spring near Kerr's Creek, Va. (auricles somewhat raised),  $\times 3.2$ .  
 Fig. 4. *Fonticola gracilis* from East Radford, Va.,  $\times 5$ .  
 Fig. 5. *Planaria dactyligera* from Big Spring near Kerr's Creek, Va.,  $\times 8.5$ .  
 Fig. 6. *Fonticola morgani* from a spring near Mountain Lake, Va.,  $\times 4.7$ .  
 Fig. 7. *Fonticola morgani* var. *polycelis* from Big Spring near Kerr's Creek, Va.,  $\times 5.3$ .  
 Fig. 8. *Procotyla typhlops* from Big Spring near Kerr's Creek, Va.,  $\times 7.6$ .

Figs. 9-14. Sketches of living animals. Abbreviations: *co.*, copulatory organs; *gp*, genital pore; *li*, limit of the area covered by the intestine; *m* mouth; *ph*, pharynx.

Fig. 9. *Curtisia foremani*,  $\times 7.8$ .  
 Fig. 10. *Fonticola gracilis*,  $\times 6$ .  
 Fig. 11. *Fonticola morgani*,  $\times 9.2$ .  
 Fig. 12. *Fonticola morgani* var. *polycelis*,  $\times 7.3$ .  
 Fig. 13. *Planaria dactyligera*,  $\times 7.8$ .  
 Fig. 14. *Procotyla typhlops*,  $\times 8.5$ .

Figs. 15 and 16. Abbreviations: *b*, bursa copulatrix; *bd*, *bd*<sub>1</sub>, stalk of the bursa copulatrix; *ca*, common atrium; *cod*, common oviduct; *ed*, ejaculatory duct; *gl*<sub>1</sub>, *gl*<sub>2</sub>, outlets of glands; *gp*, genital pore; *i*, intestine; *m*, mouth; *ma*, male atrium; *od*, oviduct; *sgl*, shell glands; *sv*, seminal vesicle; *v*, vagina; *vd*, vas deferens.

Fig. 15. *Curtisia foremani*, diagram of the copulatory organs in longitudinal section,  $\times 160$ .  
 Fig. 16. *Eplanaria tigrina*, diagram of the copulatory organs in longitudinal section,  $\times 70$ .

Figs. 17-20. Abbreviations: *b*, bursa copulatrix; *bd*, stalk of the bursa copulatrix; *c*, egg capsule (cocoon); *cvd*, common vas deferens (seminal duct); *d*, disc of the stalk of the cocoon; *ed*, ejaculatory duct; *fl*, fibrous layer; *gp*, genital pore; *j*, jellylike substance surrounding the egg capsule; *ma*, male atrium; *od*, oviduct; *pb*, penis bulb; *php*, pharyngeal pocket; *st*, stalk of the cocoon; *sv*, seminal vesicle; *vd*, vas deferens.

Fig. 17. *Fonticola gracilis*, diagram of the copulatory organs in longitudinal section,  $\times 56$ .  
 Fig. 18. *Fonticola morgani* var. *polycelis*, head (from a whole mount),  $\times 141$ .

Fig. 19. *Planaria dactyligera*, egg capsule,  $\times 17$ .

Fig. 20. *Euplanaria dorotocephala*, egg capsule,  $\times 15$ .

Figs. 21–24. Abbreviations: *b*, bursa copulatrix; *bd*, *bd<sub>1</sub>*, *bd<sub>2</sub>*, stalk of the bursa copulatrix; *cgl*, cyanophilic glands; *cm*, circular muscles; *cod*, common oviduct; *ed*, ejaculatory duct; *gl*, outlets of glands; *gp*, genital pore; *i*, intestine; *m*, mouth; *ma*, male atrium; *mp*, muscular point of the penis; *n.* ventral nerve cord; *od*, oviduct; *ods*, oviduct of the left side; *oed*, opening of the ejaculatory duct; *pb*, penis bulb; *pp*, penis proper (papilla); *t*, testis; *vd*, vas deferens.

Fig. 21. *Fonticola morgani* (from Whiskey Creek, near Churchville, Va.), diagram of the copulatory organs in longitudinal section,  $\times 95$ .

Fig. 22. *Fonticola morgani* (from a spring near Mountain Lake, Va.), diagram of the copulatory organs in longitudinal section,  $\times 82$ .

Fig. 23. *Fonticola morgani* (the same specimen as in fig. 22), structure of the penis,  $\times 82$ .

Fig. 24. *Fonticola morgani*, cross section through the prepharyngeal region, showing the situation of testes, vas deferens, and oviduct,  $\times 35$ .

Figs. 25–26. Diagrams of the reproductive system. The female organs are shown on the left, the male organs on the right side. Yolk glands (vitellaria) are omitted. Abbreviations: *ad*, adenodaetyl; *b*, bursa copulatrix; *fsv*, false seminal vesicle; *n*, ventral nerve cord; *od*, oviduct; *ov*, ovary (germmary); *p*, penis; *pb*, penis bulb; *ph*, pharynx; *t*, testes; *vd*, vas deferens.

Fig. 25. *Planaria dactyligera*,  $\times 13.5$ .

Fig. 26. *Procotyla typhlops*,  $\times 14.5$ .

Figs. 27 and 28. Diagrams of the copulatory organs, drawn from longitudinal sections. Abbreviations: *b*, bursa copulatrix; *bd*, stalk of the bursa copulatrix; *cm*, circular muscles; *cod*, common oviduct; *cvd*, common vas deferens (seminal duct); *cd*, ejaculatory duct; *epr*, epithelial lining of the prostate; *f*, fibrous layer; *gl*, outlets of glands; *gp*, genital pore; *la*, lumen of the adenodaetyl; *lm*, longitudinal muscles; *m*, mouth; *ma*, male atrium; *od*, oviduct; *ods*, oviduct of the left side; *pgl*, penis glands; *pr*, prostate; *sv*, seminal vesicle; *vd*, vas deferens; *vds*, vas deferens of the left side.

Fig. 27. *Planaria dactyligera*,  $\times 115$ .

Fig. 28. *Procotyla typhlops*,  $\times 98$ .

Fig. 29. Map of the state of Virginia, showing the distribution of planarians. The numbers correspond to the localities mentioned in the text. Localities lying close together are represented by a single sign accompanied by more than one number. The extreme western part of the state, where no planarians were collected, is omitted from the map.

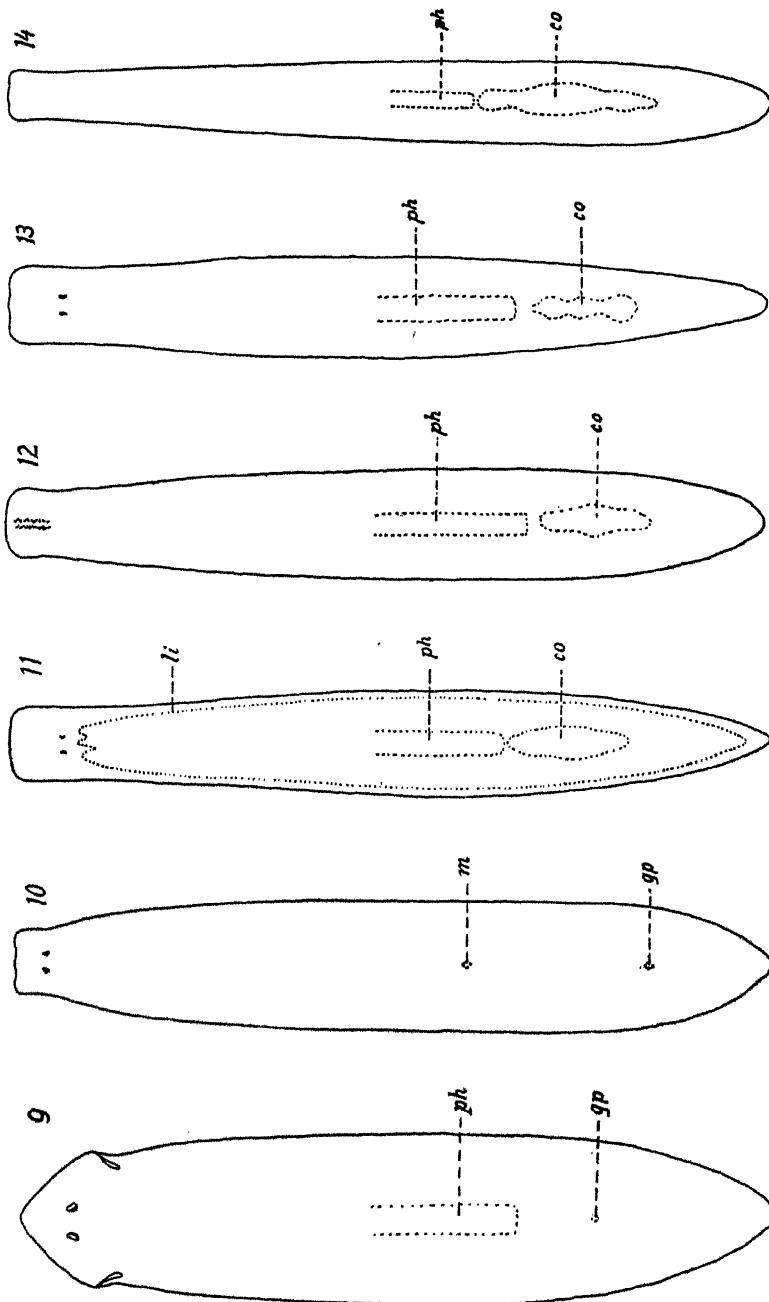


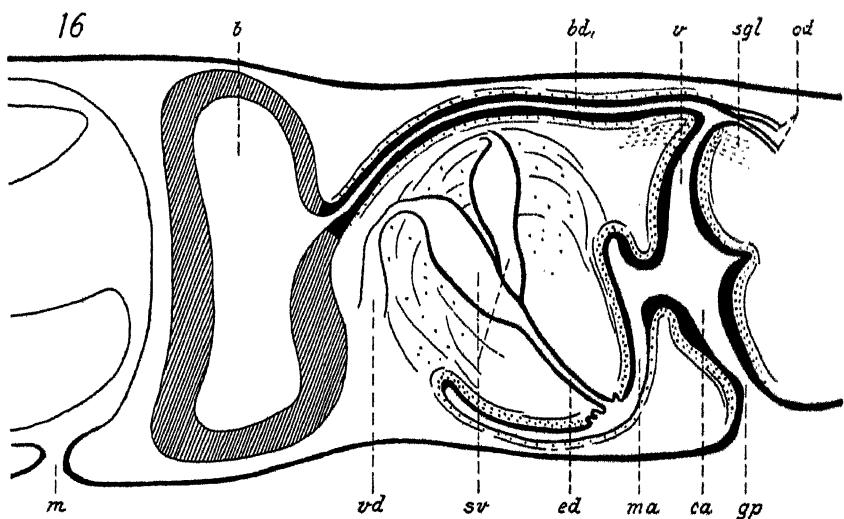
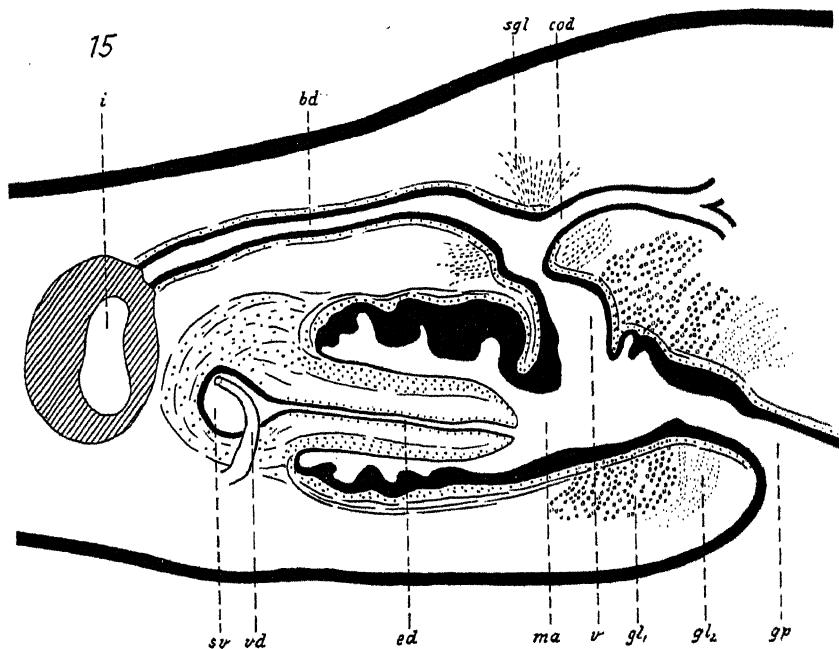
PLATE 45



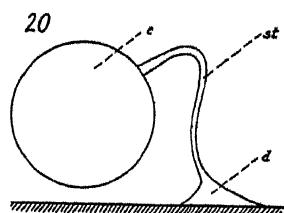
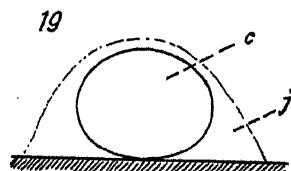
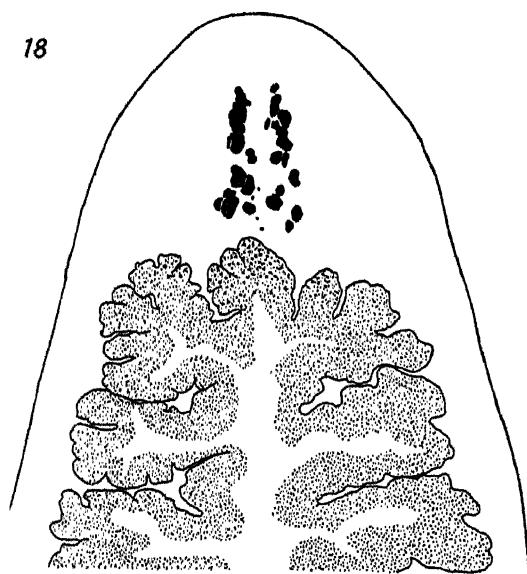
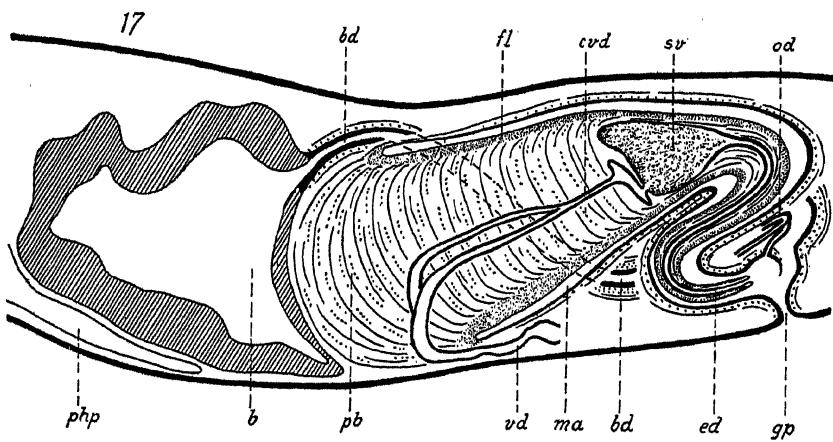


Figs. 9-14



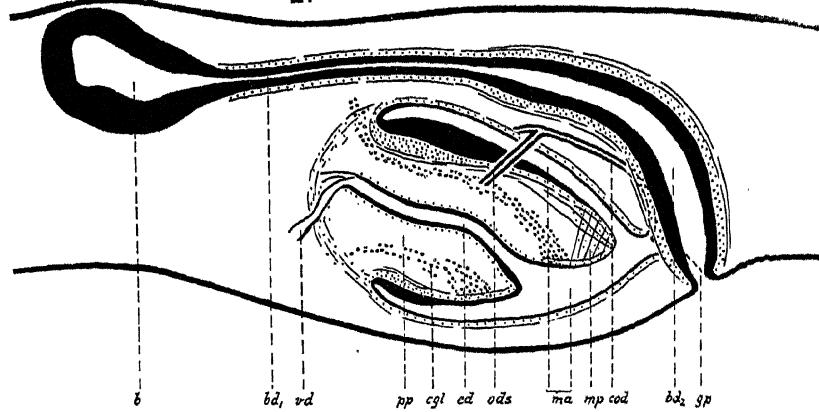


FIGS. 15-16

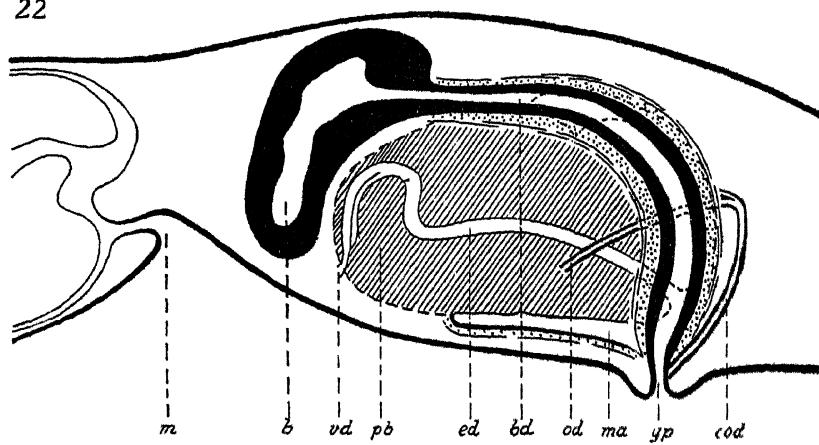


Figs. 17-20

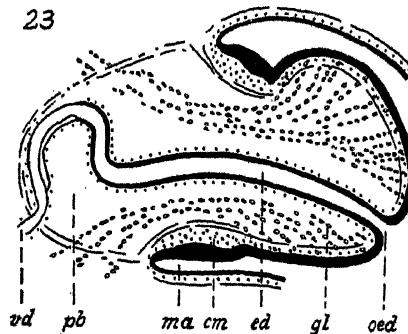
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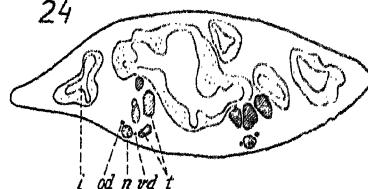
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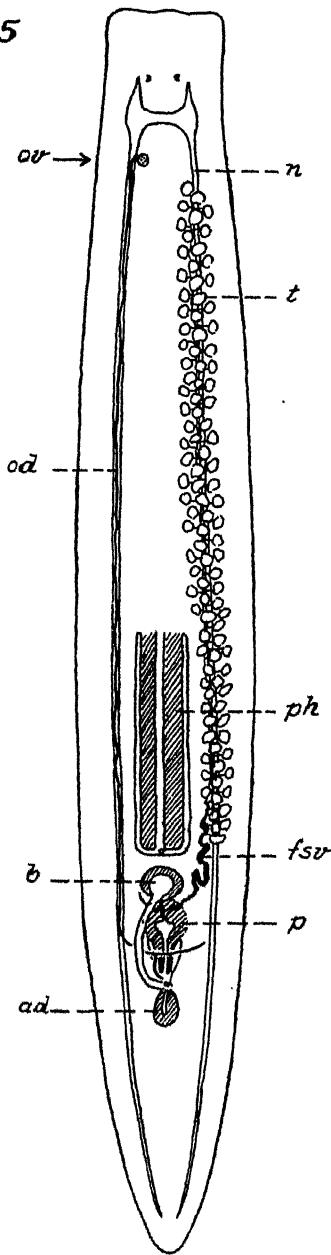


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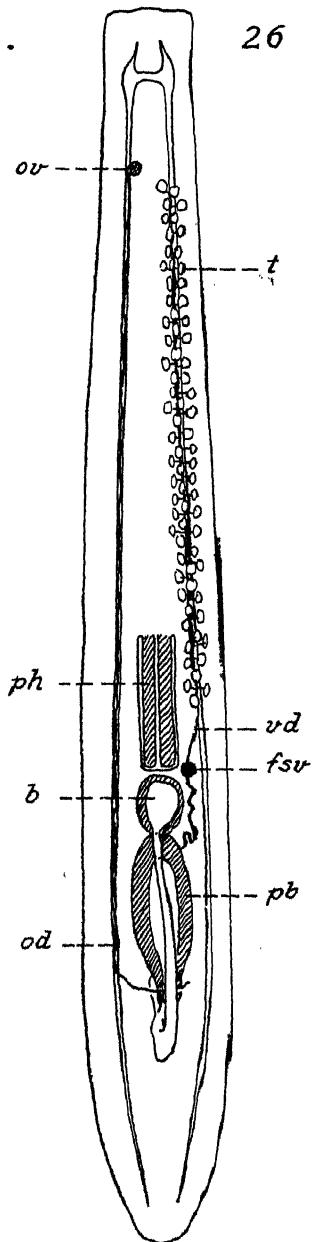


FIGS. 21-24

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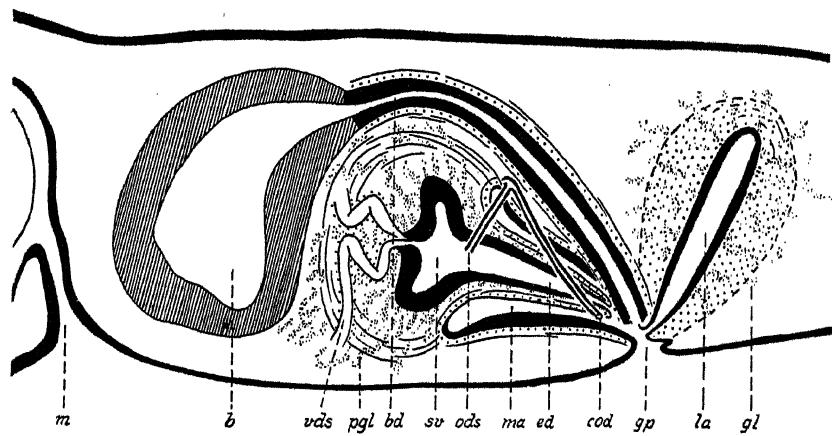


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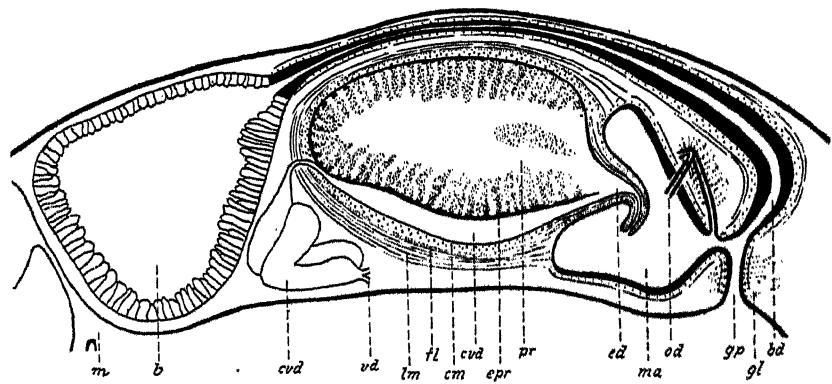


FIGS. 25-26

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FIGS. 27-28

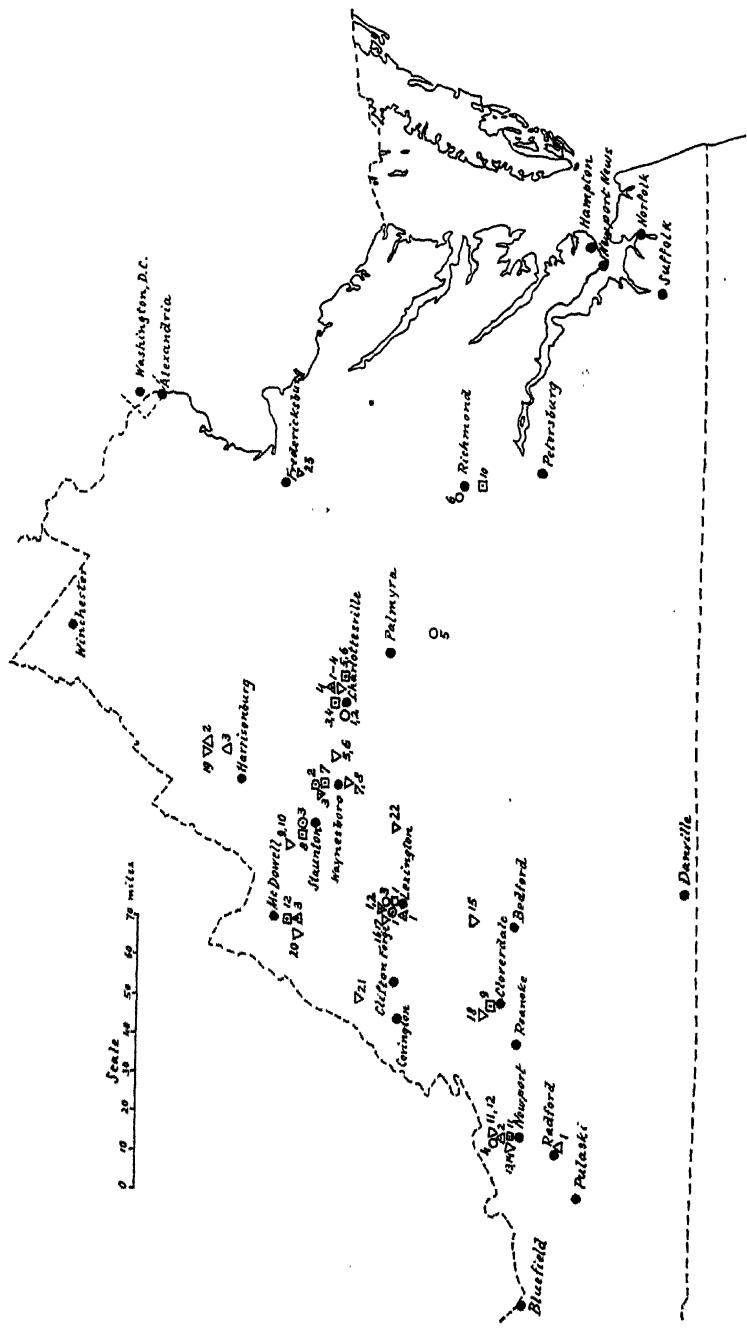


FIG. 29

- *Curtisia foremani*.
- *Euplanaria ligrina*.
- *Euplanaria dorofoca*

- △ *Fonticola gracilis*.
- ▷ *Fonticola morgani*.
- ▽ *Fonticola morgani*.

△ *Planaria dactyligera*.  
□ *Proctotyla typhlops*.



## INSPECTIONAL ANALYSIS: A METHOD WHICH SUPPLEMENTS DIMENSIONAL ANALYSIS

By ARTHUR EDWARD RUARK

Dimensional analysis has proved extremely useful in many fields of engineering and physics, especially since 1922, when access to its methods was made easy by the publication of Bridgman's "Dimensional Analysis" (1). It is significant that in this book much space is devoted to common misconceptions. The truth is, dimensional analysis has its limitations and difficulties as well as its advantages. This paper outlines a simple and workable method which yields information similar to that obtainable by dimensional reasoning. It consists in transforming the equations of a problem, differential or otherwise, so that all the variables are dimensionless. Simple inspection then shows how these dimensionless variables are related. We shall name the method *inspectional analysis*, for this term describes it well. The essential idea of the method is briefly stated in Bridgman's book, and Norman Campbell (3) has urged its adoption on several occasions. Our present purpose is the practical one of explaining the method fully, and applying it to a simple problem in which it yields more information than dimensional analysis. Previous writers have not indicated how one can make effective use of *the physical information contained in initial conditions and boundary conditions*. (See example, Section 3.) In some cases, the method presents no advantage over dimensional analysis, but in others, it gives a clearer physical insight.

### 1. DISCUSSION OF BUCKINGHAM'S PI THEOREM AND DIMENSIONAL CONSTANTS

It will first be convenient to state certain definitions and theorems of dimensional analysis. "Fundamental quantities" are those in terms of which other physical quantities are defined. In mechanical problems, it is customary to take length, mass and time as fundamental; these quantities being denoted by  $L$ ,  $M$ , and  $T$  in dimensional equations. Quantities defined in terms of the fundamental ones may be called

"derived," velocity being an illustration.<sup>1</sup> The basic axiom of dimensional reasoning is that the relative magnitude of two physical quantities of the same kind cannot be altered by any change of unit size. In applying this axiom, a mistake is often made by assuming that the quantity sought is a product of powers of the variables on which it depends. Thus, let us consider how the period  $P$  of a simple pendulum depends on length  $l$ , linear amplitude  $A$ , and on the acceleration of gravity. If we assume that  $P$  is given by the formula  $P = kl^a g^b A^c$ , the dimensional equation is  $T = L^a (L/T^2)^b L^c$ . To satisfy the basic axiom, the exponents of  $L$  and  $T$  must be the same in both members of this equation. Comparison shows that  $b = -1/2$ , and  $a + c = 1/2$ , but  $a$  and  $c$  cannot be separately determined. Therefore,

$$P = k(l/g)^{1/2} f(A/l)$$

where  $k$  is a pure number and  $f$  an arbitrary function of the dimensionless ratio  $A/l$ .

Sometimes the discovery of dimensionless variables on which a sought-for quantity depends causes difficulty, and it is desirable to know how many such variables to expect. The answer is supplied by the pi theorem of Buckingham (2).

Let  $f$  be the quantity for which we seek a formula, and let it depend on other quantities  $g$ ,  $h$ , etc., either fundamental or derived. Then the desired relation is

$$\varphi(f, g, \text{etc.}) = 0. \quad (1)$$

Suppose the variables of  $\varphi$  are  $n$  in number, and that they may be expressed in terms of  $r$  fundamental variables  $x, y, \text{etc.}$ . It is further assumed that eq. (1) is "complete," that is, all its numerical coefficients

<sup>1</sup> Often there is confusion as to the number of fundamental quantities which must be employed. One may feel it is unnecessary to introduce absolute temperature as a fundamental quantity, because it is proportional to the average kinetic energy of a gas molecule. The correct view is that we should use just as many fundamental quantities as the number of types of measurement-operations which must be specified before we can measure the quantities involved in our problem. In a *phenomenologic problem*, that is, one in which we neglect the atomic nature of matter, we are at liberty to introduce temperature as a fundamental quantity, thereby making it unnecessary to use lengths, masses, and times associated with individual molecules.

are dimensionless.<sup>2</sup> The pi theorem then states that eq. (1) can be put into the form

$$F(\pi_1, \pi_2, \dots) = 0, \quad (2)$$

where the  $\pi$ 's are dimensionless in all the fundamental variables, and are  $n-r$  in number. Often it is convenient to solve eq. (2) for the quantity  $f$ , which must be contained in one or more of the  $\pi$ 's. If it happens that  $f$  appears only in one of the  $\pi$ 's, say  $\pi_1$ , which may be of the form  $fg^ah^b$ , we have

$$f = \frac{1}{g^ah^b} D(\pi_2, \dots, \pi_{n-r}) \quad (3)$$

where  $D$  is an arbitrary function of its variables.

In setting up eq. (1), we are usually obliged to include a number of dimensional constants among the quantities  $f$ ,  $g$ , etc. A *dimensional constant* is one whose numerical value can be changed by altering one or more of the fundamental units. The gravity constant  $g$  in the pendulum problem is an example. In any practical problem, we employ as few dimensional constants as possible, for they count as additional variables in the function  $\varphi$  whose properties we wish to investigate. It may even happen that the number of dimensional constants,  $q$ , is so large that  $n+q-r$  is larger than  $n$ ; if so, the number of dimensionless variables in eq. (2) is larger than the original number of variables  $n$ , and we may not gain any advantage by throwing our equation into the form (2) or (3). This difficulty is all the more likely to occur because of the fact that when we write out our list of variables, we try not to leave out any variable, being certain that if we do, we shall not obtain a correct result. Suppose, for example, we desire to find the drag per unit length of an airplane wing. This may depend on the cross-sectional dimensions of the wing, on the pressure and density of the air, and on the velocity of the plane. The question now arises whether the velocity of sound should be included in our list. We feel intuitively that it will be convenient to have this velocity in our result, even though it depends only on the pressure and density of the air and on the ratio of the specific heats at constant pressure and at constant volume.

<sup>2</sup> For example, if a falling body starting from rest moves a distance  $s$  in time  $t$ , the equation  $s = 1/2 gt^2$  is complete, but the equation  $s = 16 t^2$  which holds in the English system of units is not complete, because the coefficient 16 is dimensional.

As a matter of fact, correct results are obtained by including the velocity of sound in the list of dimensional constants and variables. The frequent occurrence of questions like this shows that we need a general method for finding the dimensional constants and variables which enter into the problem. This is supplied in the following section.

## 2. PRINCIPLES OF INSPECTIONAL ANALYSIS

When we write down the differential equations and boundary or initial conditions of our problem, or of some problem of the same type characterized by simpler geometrical and kinematic conditions, then the variables can always be replaced by dimensionless ones. When this has been done, a formal solution of the equations may be obtained by writing each dependent dimensionless variable as a power series (or some other series capable of representing an arbitrary function), in which the arguments are the independent dimensionless variables. To understand the connection of these variables we do not have to carry through the series solution; we only need to perceive that *the dimensionless variables and combinations of dimensional constants which occur in the final integrated form of the equations are exactly those occurring in the original differential equation and the boundary or initial conditions.*

## 3. AN EXAMPLE: VIBRATIONS OF A STRETCHED WIRE

Let us illustrate the inspectional method by discussing a very familiar problem. We have a standing sine wave on a stretched wire which lies along the  $x$ -axis between the points  $x = 0$  and  $x = L$ , when at rest. Let the mass per unit length be  $D$  and the tension  $T$  and let  $y$  be the transverse displacement of the wire at any point  $x$ , at any time  $t$ . The differential equation is

$$\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}, \quad (4)$$

where  $v$  is the velocity of waves on the wire, namely,  $(T/D)^{1/2}$ . To be definite, we shall suppose the initial conditions are:

$$y = A \sin \frac{\pi x}{L} \text{ when } t = 0; \quad (5)$$

$$\frac{\partial y}{\partial t} = 0 \text{ when } t = 0. \quad (6)$$

$A$  is the arbitrary amplitude of vibration. The solution satisfying (4), (5), and (6) is easily obtained, but our present purpose is to get as much information as we can without solving the differential equation. Since equation (5) is linear,  $y$  must be proportional to  $A$ , so it is logical to employ the dimensionless quantity  $y/A$  as a dependent variable. Equation (5) suggests  $x/L$  as another convenient variable. Multiplying both sides of equation (4) by  $L^2/A$ ,

$$\frac{\partial^2 \left( \frac{y}{A} \right)}{\partial \left( \frac{vt}{L} \right)^2} = \frac{\partial^2 \left( \frac{y}{A} \right)}{\partial \left( \frac{x}{L} \right)^2}, \quad (4')$$

and the solution must be

$$y/A = f(x/L, vt/L), \quad (7)$$

where  $f$  is an arbitrary function and may contain any number of dimensionless constants. Putting  $t = 0$ , we see that (5) and (6) are satisfied. This concludes the inspectional analysis, but the problem is now in such simple form that we can get further information. The form of (5) suggests that we write  $y/A$  as a double Fourier series with undetermined coefficients:

$$y/A = \sum_m \sum_n C_{mn} \sin(m\pi x/L) \cos(n\pi vt/L) + \text{etc.} \quad (8)$$

Then it is easy to see that only the term  $A \sin \pi x/L \cos \pi vt/L$ , satisfies all the conditions of the problem.

Let us now study the problem by dimensional analysis. Equation (1) takes the form,

$$\varphi(y, x, t, T, D, A, L) = 0. \quad (1')$$

The fundamental variables are length, mass and time, so the number of dimensionless variables must be 7 minus 3 or 4. Since we employed (5) and (6) in the inspectional analysis, it is only fair to give the dimensional analyst corresponding grist for his mill. We tell him, "When  $t = 0$ ,  $y/A$  is a function only of  $x/L$ ; and  $\partial y/\partial t$  is zero." His problem is to seek four independent dimensionless quantities. After reflection, he suggests that

$$y/A = F(x/L, A/L, vt/L),$$

whereas, the previous treatment showed clearly that  $A/L$  does not occur in the solution. The reader may say, "It is not surprising that one can get more out of qualitative study of the differential equation than out of mere dimensions." I agree; it is not surprising.

#### 4. DISCUSSION

Let us now compare dimensional analysis and inspectional analysis. Both have their strengths and weaknesses. Dimensional analysis is rapid, and, in simple problems, aided by the physical common sense of the user, it often yields all the information we want. Inspectional analysis is certainly capable of yielding all the information which can be obtained by dimensional analysis, and it may yield more. In most problems, the dimensional constants may be divided into two classes: (1) those which enter into the general differential equations, and, (2) those which enter into the initial and boundary conditions, and so pertain only to the problem in hand. In using the method of inspection, we can see automatically in which class a given constant belongs. In problems which can be treated by kinetic methods, the inspectional method guards us against writing down too many dimensional constants (such as the mass of a molecule, or its radius); this may occur in using dimensional analysis because of mental fluctuations between the molecular and large-scale points of view.

Finally, dimensional analysis furnishes no way by which we may see where the difficulty lies if we make a mistake or arrive at an absurd result. In using the inspectional analysis, we are always in a position to employ straightforward physical arguments. Automatically, it shows us where we lack information. We can, for example, see clearly whether we have knowledge of all the boundary and initial conditions necessary to make our problem definite. Often a difficulty can be removed if we can only formulate it clearly.

To summarize, inspectional analysis really consists in taking the first steps toward the actual solution of a problem, and the essential points are: (1) that in taking these steps we can automatically and systematically obtain all the information supplied by dimensional analysis, and, (2) that very often additional useful information is obtained.

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## THE CHEMICAL COMPOSITION OF THE CHINA BERRY (MELIA AZEDARACH)

By R. W. BOST and DAN FORE, JR.

Chemical data on *Melia Azedarach* are meager in spite of the fact that the tree has been known for centuries. Extracts have been made of the bark, seeds, and leaves almost since the dawn of history and have been used as a panacea for many ills in various parts of the world. A few of these are mentioned herein.

In 1830 Barton mentioned *Melia Azedarach* as being the most active anthelmintic known at that time. The dried berries in spirits were employed against ascarides, tapeworm, and verminous maladies in general (11). The pulp of the berry boiled in lard has been used as an ointment in treating scalded scalps (11), while the pulp mixed with tallow has been used as an "antisporic" in the case of tinea capitis (2). The berry has also been used in the treatment of catarrh (12), in the eradication of moths (11) and in the preparation of soap. In some cases the leaves of the tree have been used as a pot herb (5) while in other cases decocted leaves have served as an astringent and stomachic as well as in the treatment of hysteria (11). Symptoms of giddiness, faintness, dimness of sight, mental confusion, and vomiting have been observed after ingestion of the sap of the tree (9). Birds, after eating the berries, show symptoms of intoxication and partial paralysis. The berries have been reported to be efficacious in the treatment of horses for "bots" (11). Through the center of the stone-like seed a hole is easily made, hence they are strung into beads which may be easily dyed any desirable color. Wherever the tree grows, it becomes known for its many berries, its blossoming odor, or some special use.

It has been reported that *Melia Azadirachta*, a kindred plant, contains margosin which is an anti-protozoal (4). This substance has been used in treating suppurating serophulus glands and leprosy.

In view of the multiplicity of uses which have been reported of *Melia Azedarach* and its physiological effects on various organisms, it seemed desirable to make a study of the chemical composition of the fruit. Since *Melia Azadirachta* has been used in treating leprosy it was thought

that *Melia Azedarach* might also contain some anti-leprosy constituent such as chaulmoogric or hydnocarpic acids or their esters.

Since certain marked physiological symptoms have been reported after ingestion of different parts of the tree, and since the berry contains 1.5 per cent nitrogen, it seemed probable that some of the common alkaloids might also be present. Aqueous solutions of the berry give strong reduction tests with Fehling's and similar solutions. The berry also gives various protein tests. The tests for alkaloids, carbohydrates, and proteins are given below together with the results.

In this paper are described the extraction of the oil, its physical and chemical properties, and the resolution and percentage of its constituents.

#### EXTRACTION OF OIL

##### 1. Acetone as Solvent

The ripe berries of *Melia Azedarach* were collected, dried two months, stemmed and the faulty fruit removed and ground to a coarse meal in a burr mill. This material was extracted by shaking with acetone at room temperature in a shaking machine for four hours. The solvent was filtered, the residue washed with cold acetone, air-dried for twelve hours, re-ground to as fine a meal as possible and extracted as before. Evaporation of the acetone was done in a continuous apparatus so arranged that the main body of the solvent dripped slowly into a distillation flask. The flask was heated on a water bath at fifty degrees and the removal of the solvent took place under diminished pressure in an atmosphere of nitrogen. The residue thus obtained contained the oleaginous material together with water, small amounts of carbohydrate and other materials. This residue was extracted with ether, the ethereal extract dried over anhydrous sodium sulfate and the extract finally evaporated as was the acetone solution. The oily material remaining in the flask is referred to in this work as whole oil. The whole oil was mixed with five volumes of petroleum ether whereupon a flocculent material which settled out was filtered off. This material was reserved for further work. The petroleum ether was removed similarly to the acetone and ether. After all the solvent had distilled, the temperature was raised to 90° and the oil treated with a rapid stream of nitrogen under reduced pressure. From 2882 g. of berries, 168.2 g. (5.83 per cent) oil was obtained.

The constants determined for the whole oil and fatty material are given in Table I.

### *2. Petroleum Ether as Solvent*

Berries prepared as described above were extracted with petroleum ether (B.P. 50°-80°) in a large Soxhlet extractor for six hours. The petroleum ether extract was then transferred to a tared flask and the solvent distilled. The oil thus obtained differed markedly in color and consistency from the acetone-extracted oil. Where the acetone-extracted oil is bright yellow, containing flocks of fat, and quite fluid, the oil from the petroleum ether-extract is reddish brown in color, viscous at room temperature and completely solidifies in an ice bath. The iodine number of this oil is 126 and the saponification value is 193.3.

TABLE I  
*Oil from Melia Azedarach*

	WHOLE OIL	FATTY MATERIAL
Specific Gravity @ 25°.....	0.9182	
Refractive Index @ 15°.....	1.4766	
Saponification Value.....	191.0	194.1
Iodine Number (Hanus).....	135.4	104.0
Acid Value.....	3.62	
Non-Saponifiable Matter.....	1.6%	

### *3. Separation of Non-Saponifiable Material*

Qualitative tests showed that the oil contained glyceryl esters of both saturated and unsaturated acids.

One hundred and sixty-six grams of pure acetone-extracted oil were saponified by boiling two hours with 750 cc. of approximately 2 N KOH. The excess alcohol was distilled off, and the non-saponified material extracted by the method of Jamieson (7). The residual alcohol-soap solution was taken up in 250 cc. of ether, and thoroughly shaken with 1200 cc. of aqueous KOH (11.2 gms. base per liter), three times with 500 cc. portions, and ten times with 100 cc. portions, care being taken not to withdraw any emulsion which was formed. The ethereal solution was washed with water until it was no longer alkaline to phenolphthalein. This extract, on evaporation, yielded 27 gms. (1.6 per cent) of non-saponifiable matter. This material was recrystallized from alcohol and finally pentane. It consisted of colorless crystals which began to soften at 120° and melted completely at 180°. It gave a negative Leibermann-Buchard test. Other tests indicated the sub-

stance was a mixture of aromatic hydrocarbons. Since only a small amount of the material was available, identification of the hydrocarbons composing the mixture was not attempted.

#### *4. Separation of the Acids*

From the soap layer, after the separation of the non-saponifiable fraction, the fatty acids were obtained by acidification with  $\text{HNO}_3$  and extraction with petroleum ether. The  $\text{HNO}_3$  for this purpose was prepared by mixing one volume of pure concentrated acid with two volumes of distilled water and then boiled to expel the oxides of nitrogen. The acid was not used until the cold solution failed to give a positive test for  $\text{NO}_2$  with starch-potassium iodide paper, since the oleic acid is converted into elaidic acid by the oxides of nitrogen. The liberated fatty acids were extracted with ether and the latter evaporated to secure the free fatty acids. The acids thus obtained had a mean molecular weight of 185. These were then dissolved in ten times their weight of boiling 95 per cent alcohol to which was added a one-half mole excess of lead acetate in an equal volume of hot alcohol. The solution was cooled to room temperature and placed in a bath at 15° for 24 hours to insure complete precipitation. The precipitate was filtered, washed several times with cold 95 per cent alcohol, then dissolved in 95 per cent hot alcohol, a few drops of glacial acetic acid added and the solution cooled as before. After filtering and washing, the filtrates from the two precipitations were combined and reserved for future use.

#### *5. The Saturated Fraction*

The precipitated lead soaps were suspended in ether, decomposed by shaking with dilute nitric acid, the acidulated lead nitrate solution drawn off in a separatory funnel, and the ethereal solution washed with water until neutral with methyl red. Evaporation of the ether extract gave a solid cake, light yellow color, consisting chiefly of a mixture of the saturated acids.

#### *6. The Unsaturated Fraction*

The alcoholic solution of the unsaturated lead soaps obtained from the separation of the saturated members in (4) was evaporated to a low volume and dilute  $\text{HNO}_3$  added in slight excess to decompose the salts and water added to take the lead salts into solution. The freed fatty acids were extracted with ether, the latter washed with water to remove the mineral acid, the solvent evaporated, and the last traces of water

removed from the liquid unsaturated acids by bubbling a stream of nitrogen through while heating under reduced pressure on a water bath at 90°. The absence of linolenic acid was proved by the Hexabromide Method (6). The weights of saturated and unsaturated acids and the percentages of each are given in Table II.

### *7. Esterification of the Acids*

The acids from the saturated and unsaturated fractions were dissolved in one and one-half times their weight of methyl alcohol containing 3.5 per cent HCl by volume. Twenty-five per cent of the fatty acid weight of freshly fused CaCl<sub>2</sub> was added and the mixture refluxed 20

TABLE II  
*Acids*

	WEIGHT	PER CENT
	gms.	
Saturated Acids (210 grams oil).....	24.05	11.45
Unsaturated Acids (210 grams oil).....	185.70	88.43

TABLE III  
*Methyl Esters*

	ACID USED	ESTER	PER CENT YIELD
	gms.	gms.	
Saturated Acids.....	20.0	20.5	90.7
Unsaturated Acids.....	170.0	172.0	97.3

hours. The esters were then separated by means of ether, washed to remove alcohol and mineral acid, and then washed four times with sodium carbonate (8 grams per liter) to remove unreacted fatty acid. The alkali was removed by water, the ether solution dried over anhydrous sodium sulfate, and evaporated in an atmosphere of nitrogen. The residue was dried under diminished pressure in a stream of nitrogen for six hours at 90°.

### *8. Fractionation of Methyl Esters*

The methyl esters of the saturated and unsaturated acids were fractionated in an atmosphere of nitrogen at a constant pressure of 5 mm. The weights of the fractions obtained are given in Table III and the distillation temperatures are given in Tables IV and V. The iodine

numbers and saponification value of each final fraction are also given. Since the esters of the unsaturated acids are not readily separable by fractional distillation, the percentage of these constituents present was

TABLE IV  
*Analysis of Saturated Esters*

B.P. OF FRACTION (5 MM.)	SAPONIFICATION VALUE	MEAN MOLECULAR WEIGHT	PER CENT METHYL PALMITATE	PER CENT METHYL STEARATE
175-9°	205.66	272.81	90.23	9.77
182-7°	198.00	283.35	51.09	48.91
Residue	189.10	296.70	5.50	94.50
Total weight of Methyl Palmitate.....				10.93 g.
Total weight of Methyl Stearate.....				8.57 g.
Per cent of Palmitic Acid.....				55.95
Per cent of Stearic Acid.....				44.05

TABLE V  
*Analysis of Unsaturated Esters*

B.P. OF FRACTION (5 MM.)	SAPONIFICATION VALUE	IODINE NUMBER	WEIGHT
			gms.
188-90°	190.2	132.90	98.4
190	190.0	147.63	25.6
191	192.7	150.15	29.5
198	.....	133.06	4.3
Residue	.....	141.23	5.3

TABLE VI  
*Analysis of Whole Fatty Acid Mixture*

Iodine Number.....	131.28
Thiocyanogen Number.....	82.88
Saturated Acids.....	11.45%
Palmitic.....	55.95%
Stearic.....	44.05%
Unsaturated Acids.....	88.43%
Oleic.....	41.81%
Linoleic.....	58.18%

determined by the thiocyanometric method of Kaufman (8). From the thiocyanogen and iodine values of the acids, simultaneous equations may be set up, the solution of which will give the percentage composition of the fatty acid mixture as indicated in Table VI.

OTHER CONSTITUENTS OF *MELIA AZEDARACH**Tests for Alkaloids and Poisonous Substances*

It has been observed that birds after eating the fruit of *Melia Azedarach* develop toxic symptoms marked by partial paralysis of the whole body and total loss of control of the wings. The latter drag limply as the intoxicated bird walks. This stage passes gradually into a period of insensibility followed usually by death. Morrison and Grant (10) found that the ground meal of the berries produced symptoms in cattle marked by incapacitation of the fore limbs. Picrotoxin, an active plant principle, causes selective paralysis of the fore limbs (3).

Five hundred grams of ground berries were extracted with 1500 cc. of hot water. To this solution was added 50 g. of magnesium oxide to precipitate the tannins and acidic substances, and the filtrate was evaporated to a syrup which was treated with five times its volume of hot alcohol. The alcohol extracts were combined, filtered, and evaporated. The residue was shaken with hot water and the solution filtered, acidified with dilute H<sub>2</sub>SO<sub>4</sub>, and extracted repeatedly with chloroform. The latter extract, on evaporation, yielded a small brownish bitter residue which failed to give any of the characteristic tests for picrotoxin. When dissolved in water and injected into the lymph sac of a healthy frog it did not show the symptoms of picrotoxin poisoning which were observed in a control poisoned with a known sample of picrotoxin.

Another attempt was made to isolate picrotoxin using the Stas-Otto Method (1). The various extracts when evaporated left a small brownish residue, none of which responded to picrotoxin tests. Negative tests were also obtained for the alkaloids listed in Autenreith and Warren (1).

It is believed that picrotoxin is absent in *Melia Azedarach* and that some unknown alkaloid of high toxicity occurs in traces, since only a small amount of this substance was obtained. There is also the possibility of the poisonous substance existing as the glucoside.

*Carbohydrates*

When an acetone extract of the ground berries is allowed to evaporate spontaneously, two layers will eventually form: a yellow oily layer which separates to the bottom and which has already been described and a top layer which is reddish in appearance. This layer was evaporated to remove the acetone and extracted with hot absolute alcohol. The latter solution was concentrated, cooled, and anhydrous ether added

in sufficient volume to precipitate the saccharide. Upon filtration, a white hygroscopic powder was obtained which gave positive Fehling's, Benedict's, and Barford's tests. It gave negative Phloroglucinol, Seliwanoff, Ammonium Molybdate, and Methyl Phenylhydrazine tests. It also gave a phenylhydrazone which melted at 205.5°. The sugar was shown to be glucose. No other carbohydrate was found.

### *Proteins*

From an aqueous extract of the berries, proteins may be precipitated by half and full saturation with ammonium sulfate. The precipitates so obtained give positive Xanthoproteic, Millon's, Biuret and Hopkins-Cole tests for proteins. The latter test was not as heavy as the others. The protein material needs further study for final classification. It is of interest to note that the presence of one or more of the few vegetable albumins which are precipitated at half saturation with ammonium sulfate is possible.

### *Discussion of Results*

The oil of the fruit of *Melia Azedarach* may be classed as a semi-drying oil. It occurs in too small a percentage (5.83 per cent) to be of any commercial importance at present. The oil consists of 11.45 per cent of saturated acids of which 55.95 per cent is palmitic acid and 44.05 per cent is stearic acid. The unsaturated acids occur in the oil to the extent of 88.43 per cent of which 58.18 per cent is linoleic and 41.81 per cent is oleic acid. The authors were unable to detect the presence of chaulmoogric or hydnocarpic acids. If the oil contains an anti-leprosy material it must be of some other nature than the aforementioned acids. No substance was found which is known to give the physiological reactions reported in the literature. Further studies on the physiological effects of the non-saponifiable fraction are being investigated. The presence of glucose in the berry has been shown which explains the behavior of aqueous solutions of the berry with reducing solutions as well as the fermentation of the aqueous solutions. Further work is necessary to definitely classify the proteins.

### SUMMARY

1. The fruit of *Melia Azedarach* has been studied and found to contain a semi-drying oil, glucose, a non-saponifiable constituent consisting chiefly of hydrocarbons, certain proteins, and a poisonous constituent of unknown constitution.

2. The oil consists chiefly of the glycerides of palmitic, oleic, linoleic, and stearic acids. No linolenic, chaulmoogrie, or hydrocarpic acids were detected.
3. The oil was extracted with various solvents and a ease of selective extraction was noted.
4. Picrotoxin was shown to be absent.

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## SOLUBILITY STUDIES IN THE SYSTEMS: BENZENE-p-NITROTOLUENE AND BENZENE-o-NITROTOLUENE

By H. D. CROCKFORD and E. C. POWELL, JR.

The purpose of the work reported in this paper was to determine the temperature-composition diagrams for the binary systems: benzene-p-nitrotoluene and benzene-o-nitrotoluene. These data show if compounds of either a stable or unstable nature are formed between the pairs and whether the solutions involved are ideal in nature. From the data may be calculated the latent heat of fusion of the components. This work is a continuation of a series of investigations on the thermal properties of the nitrotoluenes which have been carried on in the Chemistry Laboratory of the University of North Carolina.

The nitrotoluenes used were the highest grade of Eastman product. The o-nitrotoluene was further purified by recrystallization from hot carbon tetrachloride and the p-nitrotoluene by recrystallization from its own melt. The benzene used was the Kahlbaum "zur Analysis" grade. It was found to be extremely pure. Constant melting points were found as follows: p-nitrotoluene, 51.4°; o-nitrotoluene, -10.4°; and benzene, 5.42°C.

The same general method of procedure as has been employed in previous investigations (Crockford and Simmons, Journ. E. M. Sci. Soc. 42: 273. 1933) was used. Mixtures were prepared as shown in Table I so as to secure sufficient data for the systems. These mixtures were made by weighing the p-nitrotoluene in the usual way, by weighing the o-nitrotoluene in a weighing burette, and by measuring the benzene from a regular pipette and then calculating its weight from the density at the given temperature. Cooling curves were then obtained from the various mixtures and the freezing and eutectic points obtained by the method of Bell and Herty, as discussed in the reference cited.

Due to the low temperatures encountered in most of the mixtures some modification of the apparatus was necessary. A vacuum bottle of one quart capacity was used as an outside vessel. Into the mouth was fitted a cork stopper through which was inserted an eight inch test tube which contained the mixture being studied. The stopper of this test

tube contained openings for the thermometer and the loop stirrer. The cooling mixture employed in the vacuum bottle for the lower temperatures consisted of ethyl ether and solid carbon dioxide. An opening in

TABLE I

SOLVENT	MOL. FRACTION SOLVENT	$\log x$	FREEZING POINT	$\frac{1}{T} \times 1000$
Benzene-p-Nitrotoluene System				
p-Nitrotoluene.....	1.000	.000	51.4	3.083
	.948	-.023	48.8	3.108
	.856	-.067	43.9	3.156
	.697	-.157	34.2	3.255
	.548	-.262	23.3	3.375
	.394	-.404	11.2	3.519
	.305	-.516	2.8	3.626
	.2500	-.602	-2.9	3.703
Benzene.....	.789	-.103	-7.2	3.762
	.798	-.098	-6.8	3.757
	.835	-.078	-4.1	3.719
	.900	-.046	-0.4	3.669
	.939	.027	+2.0	3.632
	1.000	.000	5.4	3.592
Benzene-o-Nitrotoluene System				
o-Nitrotoluene.....	1.000	.000	-10.4	3.808
	.869	-.061	-16.7	3.902
	.752	-.124	-23.3	4.005
	.663	-.179	-28.6	4.092
	.594	-.226	-32.4	4.162
Benzene.....	.475	-.323	-29.9	4.114
	.550	-.260	-25.0	4.032
	.700	-.155	-14.1	3.862
	.800	-.097	--7.2	3.762
	.908	-.042	--0.3	3.667
	1.000	.000	+5.4	3.592

the cork of the vacuum bottle allowed the carbon dioxide gas to escape. These cooling mixtures were held a few degrees below the freezing points of the various melts. In some cases "seeding" had to be employed to prevent excessive supercooling. In some of the low temperatures ice

was formed in the melt from the moisture in the air of the test tube. This trouble was partially overcome by passing dry nitrogen gas into the tube.

For the higher temperatures mercury thermometers were employed. For the lower temperatures it was necessary to use pentane thermometers. All thermometers were properly calibrated.

In Table I are given the data for the compositions and freezing points of the various mixtures. The table also includes the  $\log x$  ( $x$  = mol fraction of solvent) and the  $1/T \times 1000$  values. Temperature-composition diagrams are not included in the paper as the systems prove to be simple in nature and include only one eutectic each. The  $\log x - 1/T \times 1000$  plots are nearly straight lines departing from the linear only in the more concentrated solutions. The temperature readings are corrected for stem exposure. It is to be noted that in Table I the freezing points are given in degrees Centigrade while the  $1/T \times 1000$  values are calculated in degrees Absolute. For the p-nitrotoluene system temperatures are accurate to  $.1^\circ$ . For the o-nitrotoluene system they are reported to the same value but they are hardly as accurate, due to the very large stem corrections which had to be applied. In some cases this correction amounted to as much as  $5^\circ\text{C}$ .

The systems show no indications of compound formation and on the whole are fairly ideal in nature. The eutectic temperatures were checked on a number of melts. The values are as follows: for the p-nitrotoluene system,  $-7.2^\circ$ ; for the o-nitrotoluene system,  $-33.3^\circ\text{C}$ .

The latent heats of fusion have been calculated by means of the equation

$$\log x = \frac{L}{2.3 R} \left( \frac{1}{T} - \frac{1}{T_0} \right) \quad (1)$$

in which  $x$  is the mol fraction of solvent in the mixture of freezing point,  $T$ .  $T_0$  is the freezing point of the pure solvent,  $R$  is the gas constant, and  $L$  the molal heat of fusion of the solvent. For the o-nitrotoluene the value of the molal heat of fusion is  $2895 \pm 25$  calories. For the p-nitrotoluene it is  $4150 \pm 50$  calories. No calorimetric values are available for comparison with the above. The values for benzene as calculated are: for the o-nitrotoluene system, 2475 calories; for the p-nitrotoluene system, 2750 calories. These are accurate to four per cent. The accepted value is 2365 calories at  $15^\circ\text{C}$ . In deriving equation (1) it is to be noted that  $L$  was considered constant in the integration of the equation from which (1) was derived. This is probably not

true. Moreover it is to be noted that the data in these two systems from which the  $L$  value for benzene is calculated extend over such a small temperature range that the use of the equation is questionable.

#### SUMMARY

1. Temperature-composition data have been obtained for the systems: benzene-p-nitrotoluene and benzene-o-nitrotoluene. The systems show no evidence of compound formation.
2. From the data have been calculated the latent heats of fusion of the components.

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## THE DETERMINATION OF ALANINE IN BIOLOGICAL MATERIALS

By E. W. McCHESNEY

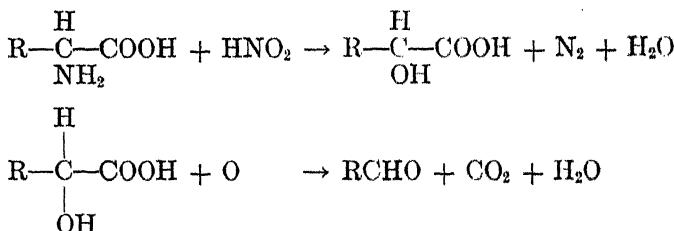
A survey of the literature would lead one to the conclusion that methods for the determination of alanine in biological materials are rather thoroughly worked out. Kendall and Friedemann (1930) have published a method for the determination of alanine in such materials as culture media, peptone solutions, meat extracts, etc., based on its conversion to lactic acid by means of nitrous acid, followed by oxidation of the lactic acid to acetaldehyde according to their rather well-known technique (Friedemann and Kendall, 1929). They reported nearly quantitative conversion of alanine to lactic acid inasmuch as 97-98 percent of the theoretical amount of acetaldehyde could be obtained as a result of these two steps. Furth, Scholl, and Herrmann (1932) have applied this method to the determination of alanine in protein hydrolysates and have reported on the alanine content of a number of proteins.

It is the experience of the author and others (Furth *et al.*, 1932, and Jukes in personal communication), however, that the method of Kendall and Friedemann falls far short of what is claimed for it. With the most cautious application of their procedure, the yield of acetaldehyde is but 90-92 percent of the theoretical, the latter figure being the best ever obtained in a long series of tests. This is about 7 percent less than the amount claimed and is a serious error if one wishes to estimate alanine accurately. This would seem to indicate that the data of Kendall and Friedemann are incorrect or that there is some complication in the method which they did not encounter.

The author has made a serious attempt to improve upon the method of Kendall and Friedemann by altering such factors in the reaction as volume, time, temperature, concentration of nitrous acid, nature of the acid used to convert sodium nitrite to nitrous acid, etc. Several of these modifications give results as good as the original and are much less laborious, but none give better results. For example, in the deamination process, 5 cc. of 10 percent acetic acid may be substituted for the concentrated HCl or sodium bisulfate recommended in the original

procedure. With this change it is necessary to shake the reaction vessel only occasionally instead of continuously during the half-hour period in the boiling water bath; results averaging 91 percent yield may be obtained even more consistently than with Kendall and Friedemann's procedure. It would appear that an equilibrium is reached at the point of 91 percent yield and no method has been found which would serve to shift it further in the desired direction. Some attempt has been made to identify the product (or products) composing the remaining 8 or 9 percent but other than the fact that it does not seem to be pyruvic acid, no definite statement can be made at this time.

In applying this technique to biological materials, it must be remembered that all of the nineteen or twenty amino acids serve as potential sources of volatile aldehydes according to the equations:



A few of the amino acids such as glutamic acid, glycine, proline, serine, arginine, and hydroxyproline yield no trace of volatile aldehyde, according to Furth *et al.* and the writer's own observations. However, even phenylacetaldehyde, b.p. 194°C., from phenylalanine, comes over to a slight extent under the conditions of the experiment and would appear in the calculations as alanine. Kendall and Friedemann have usually assumed that these higher-boiling aldehydes would be held back by the reflux condenser. Some of the interfering compounds derived from the other twelve or thirteen amino acids<sup>1</sup> may be removed preliminary to oxidation by precipitation as the lead salts of the hydroxy acids (McChesney, 1934), but others such as valine, leucine, isoleucine, etc., give much trouble. Furth and co-workers attempted to get around the difficulty presented by these compounds by a careful fractional distillation of the aldehydes, seeking to hold back those boiling at temperatures higher than acetaldehyde. (Isobutyraldehyde, b.p. 63°C., from valine, is the nearest to acetaldehyde, b.p. 21°C.: the problem is obviously not a simple one.)

<sup>1</sup> Notably cystine, phenylalanine, tyrosine, lysine, histidine, and aspartic acid. For outline of method see McChesney (1934).

The results obtained with this method in the hands of other workers (Jukes, personal communication) have not been encouraging, however, and it would seem advisable to remember in applying the original method for alanine, at least, that many substances are reacting to some extent and will affect the values obtained.

The work of Furth, Scholl, and Herrmann is worthy of some detailed comment. They have used Kendall and Friedemann's technique for the determination of alanine in protein hydrolysates freed from the diamino and dicarboxylic acids. They report determinations on amounts of solution representing 0.8 to 16 mg. of protein. In the case of silk fibroin, which contains about as much alanine as any protein (25 percent), this would represent 0.2 to 4 mg. of alanine in the solution analyzed and would require for the final titration 0.45 to 9 cc. of 0.01 N iodine solution, while a blank usually requires about 0.15 cc. of the same. These results seem reasonable, at least when quantities of 4 mg. of alanine are being determined, but most of their determinations were made on quantities of protein smaller than 5 mg. and with proteins containing much less than 25 percent of alanine. In fact, some of their determinations would have required as little as 0.2 cc. of 0.01 N iodine, hardly more than a blank. In the experience of the author quantities of alanine less than 2 mg. (requiring 4.5 cc. of 0.01 N iodine) cannot be determined with any degree of accuracy<sup>2</sup> even when the fractional distillation step is omitted, and it hardly seems possible that determinations accurate within several hundred percent could have been made on such minute amounts of material when one considers the difficulty of the manipulations involved. The authors have not suggested any reason for using these very small quantities. The work of Jukes (1933) in this connection is of significance. He attempted to use the method of Furth and co-workers for the determination of alanine in livetin and says (personal communication) that by the time pure solutions of alanine were carried through the deamination, oxidation, and fractional distillation procedures only about 70 percent of the alanine could be accounted for, even when the fractional distillation was carried on for a much longer time than directed. The paper of Furth *et al.* also records results obtained when known amounts of alanine were added to the protein solutions under examination and reports recovery averaging 92 percent. Recalculation of the results shows, however, that the recovery really averaged 90 percent and was therefore in many cases less.

<sup>2</sup> This was also the experience of Kendall and Friedemann.

In the light of these facts, it would appear that the work on the determination of alanine needs considerable revision. The first requisite for significant progress is a method which will convert alanine quantitatively to lactic acid. If none can be found it must become generally recognized that a correction factor of 9 percent is to be applied to the results.

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## THE STOMATOPODS (MANTIS SHRIMPS) OF THE CAROLINAS

By G. ROBERT LUNZ, JR.

### FIGURES 1-6

An examination of the literature pertaining to the mantis shrimps shows that prior to the present one, three lists<sup>1</sup> of stomatopods have been published for the Carolinas. In 1848, Gibbes appended a faunal list to Toumey's Report on the Geology of South Carolina. In this list four species were recorded. In 1878, Coues and Yarrow in their Fort Macon Fauna Report list a single species. In 1883, L. O. Howard compiled a hypothetical list of the Invertebrate Fauna of South Carolina and listed five species. Since 1883 several changes have been made in the classification of the stomatopods, a new genus has been added to those recorded for the two states, ranges have been extended, and records of rare species have been substantiated. This leads me to believe that a new list for the Carolinas will be of value.

The present list is based on the material to be found in the collection of the Charleston Museum at Charleston, S. C.; the U. S. Bureau of Fisheries Biological Station at Beaufort, N. C.; the University of North Carolina at Chapel Hill, N. C.; and the North Carolina State Museum at Raleigh, N. C. In addition to studying the above mentioned material, I have been allowed to examine the records and many of the specimens in the U. S. National Museum.

I wish to express my gratitude to the authorities at the U. S. National Museum for the privilege of examining their collection. Also, I am duly grateful to the Bureau of Fisheries for the courtesies extended me at its Biological Station at Beaufort, N. C. It is a privilege to be able to acknowledge the help of Dr. Waldo L. Schmitt of the U. S. National Museum. I am also grateful to Dr. H. V. Wilson of the University of North Carolina, Dr. H. H. Brimley of the N. C. State Museum, Mr. Paul

<sup>1</sup> I omit specific mention of Bigelow (1894), Brooks (1886), Gibbes (1850), and Kingsley (1878) not because of a lack of appreciation of the value of their work but because either they did not publish a list of stomatopods or because their lists do not deal solely with North or South Carolina species.

R. Weidner of the College of Charleston, and Mr. E. Burnham Chamberlain of the Charleston Museum.

The stomatopods are represented in the Carolinas by 6 species, distributed through 3 genera, as follows: *Gonodactylus*, 1; *Lysiosquilla*, 2; and *Chloridella*, 3. In the earlier records the mantis shrimps of the genus *Chloridella* were called *Squilla*. This name is no longer in good standing (see Rathbun, 1902, p. 54, foot note) though often used nowadays to refer to the stomatopods in a general way.

The key which follows is based on a few simple characters and will serve to differentiate the genera. This key, however, is devised to apply only to those stomatopods recorded for North and South Carolina.

#### KEY TO GENERA OF STOMATOPODS IN NORTH AND SOUTH CAROLINA

A<sup>1</sup> Raptorial claw dilated at base; dactylus without teeth; eyes dilated. *Gonodactylus*.  
A<sup>2</sup> Raptorial claw not dilated at base; dactylus bearing 5 or more teeth.  
B<sup>1</sup> Dactylus with 9 or more teeth.....*Lysiosquilla*.  
B<sup>2</sup> Dactylus with 5 or 6 teeth.....*Chloridella*.

#### *Gonodactylus oerstedii* Hansen

*Gonodactylus oerstedii* Hansen, Isopoden, Cumaceen und Stomatopoden, Ergeb. d. Plankton. Exped. II (1895), p. 65, foot note.

*Diagnostic characters:* A *Gonodactylus*, the dactylus of the raptorial claw of which bears no spines and is dilated at the base. The posterior portion of the body is decidedly convex and strongly built. The rostrum bears an acute spine which is about one-half the width of the entire rostrum. The dorsal surface of the telson is not spiny. The first exposed thoracic segment has no lateral process. The eyes are cylindrical.

*Remarks:* The Charleston Museum has in its collection a dried specimen presumably taken off Charleston Harbor. This specimen formed a part of the L. R. Gibbes Collection. A catalogue card states that a specimen of this species was in the Gibbes Collection and that it was collected in South Carolina. It is probable that the specimen under discussion is the one mentioned on the catalogue card. The National Museum has a specimen from Cape Fear, N. C. It also has a much-mangled specimen taken off Charleston Harbor, which is doubtfully determined as this species. There are two specimens at the Bureau of Fisheries Biological Station at Beaufort, N. C. These specimens were taken by the "Fish Hawk" off Beaufort, N. C., May,

1907. (I have not been able to differentiate the few specimens I have examined into varieties as described by Dr. Schmitt, 1919, p. 96.)

It is evident that this species is not common in the Carolinas. It is known to occur southward from North Carolina and Bermuda to Brazil, including the Bahamas, the West Indies, and the Gulf of Mexico. It is also recorded from the Gulf of California.

The genus *Lysiosquilla* is represented in North and South Carolina by two species.

#### KEY TO THE SPECIES OF *LYSIOSQUILLA* IN NORTH AND SOUTH CAROLINA

- A<sup>1</sup> Dactylus of raptorial claw with more than 10 teeth, eyes cylindrical with hemispherical cornea.....*excavatrix* Brooks
- A<sup>2</sup> Dactylus of raptorial claw with 9 or 10 teeth, eyes T-shaped with bilobed cornea.....*scabrida* Lamarck

#### *Lysiosquilla excavatrix* Brooks

*Lysiosquilla (Coronis) excavatrix* Brooks, Report on the Stomatopoda, Voyage of Challenger, Zool., XVI, II, p. 48.

*Diagnostic characters:* A *Lysiosquilla* having 15 or 16 teeth on the dactylus of the raptorial claw. The cylindrical eyes have hemispherical cornea. In one specimen the diameter of the eye is 2 mm. The telson of *excavatrix* is rectangular in shape. On its ventral surface are two lateral spines which are large and movable. Between these are 9 or 10 small immovable spines.

*Remarks:* This species was described by W. K. Brooks from specimens taken at Beaufort, N. C. I have examined only two specimens of this species: One at Beaufort, N. C., and one kindly loaned by Dr. H. V. Wilson of the University of North Carolina. Both specimens were taken at Beaufort, N. C. The specimen in the Bureau of Fisheries Biological Station checked very closely with Brooks' description of this species. The specimen from the University of North Carolina checks in most characters with the original description except that the dactylus of the raptorial claw had only 13 teeth. Brooks (1886, p. 50) states that there are no structural differences between the sexes of *excavatrix*, except in the organs of reproduction. Therefore, it would seem that this difference in the number of teeth is not due to a difference in sex. I have not examined a sufficient number of specimens to form an opinion as to the cause of this variation.

The species is reported as being common at Beaufort, N. C. It has not been taken in South Carolina but the United States National Museum has a specimen for Charlotte Harbor, Florida, taken by the

"Albatross" at Station 2410. The Museum of Comparative Zoology has two specimens from Mobile, Alabama (No. 7904).

**Lysiosquilla scabricauda (Lamarek)**

*Squilla scabricauda* Lamarek, Hist. Anim. sans Vert. 5: 188. 1818.

*Diagnostic characters:* A *Lysiosquilla* having 9 or 10 strong teeth on the dactylus of the raptorial claw. The T-shaped, bilobed eyes are set at a slight angle to the stalk. In one specimen the corneal axis of the eye is 11 mm. while the peduncular axis is 8 mm. The posterior part of the body is depressed and triangular in shape. The telson is spinulose. The lateral processes of the first exposed thoracic segment are not produced.

*Remarks:* The Charleston Museum has two specimens: One was taken off Charleston Harbor by a fisherman in the summer of 1931; the other specimen is a Gibbes specimen. The label with the latter does not give the date of collection and for the locality gives only South Carolina. It is probable, however, that it was collected before 1850 in or near Charleston Harbor. The species ranges southward from South Carolina to Brazil, including the Bahamas, West Indies, and the Gulf of Mexico. It has also been recorded from West Africa.

The genus *Chloridella* (*Squilla* of most authors) is represented in the Carolinas by three species.

**KEY TO SPECIES OF CHLORIDELLA**

- A<sup>1</sup> Dactylus of raptorial claw with 5 teeth; lateral process of first exposed thoracic segment spatuliform; median dorsal spine of telson long and slender; eyes large.....*neglecta* (Gibbes)
- A<sup>2</sup> Dactylus of raptorial claw with 6 teeth.
  - B<sup>1</sup> 5 teeth well developed, 6th very small; eyes small; lateral process of first exposed thoracic segment spiniform; median dorsal spine on telson blunt; median carina on carapace not bifurcate.....*dubia* (M. Edwards)
  - B<sup>2</sup> All 6 teeth well developed; eyes large; lateral process of first exposed thoracic segment spiniform; median dorsal spine on telson short; median carina on carapace bifurcated anteriorly.....*empusa* (Say)

***Chloridella neglecta* (Gibbes)**

*Squilla neglecta* Gibbes, Proc. Amer. Assoc. Adv. Sci. 3: 200. 1850.

*Diagnostic characters:* Dactylus of raptorial claw bears 5 teeth. The median dorsal spine of the telson is very pronounced, being at least 2 mm. long. The lateral processes of the first exposed thoracic segment are produced into a bifurcate spine, the uppermost part being spatuli-

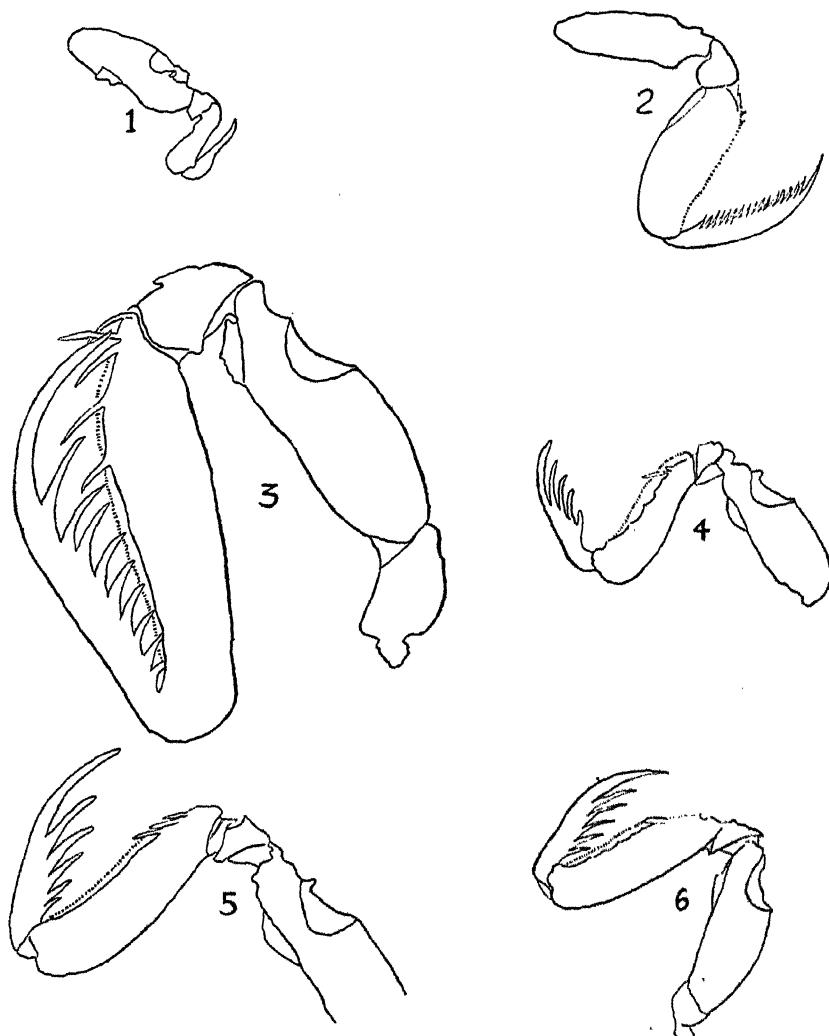
form. The median carina of the carapace is bifurcate. The eyes, like those of *empusa*, are large.

*Remarks:* This species was originally described by L. R. Gibbes from a specimen taken in Charleston Harbor in 1848. For 85 years no other specimen of *neglecta* was reported and, as far as I have been able to ascertain, no specimens of this species existed since Gibbes' type specimen was destroyed. However, on October 31, 1933, a specimen was obtained from a local shrimp trawler working off Charleston Harbor. This rediscovery was published in Leaflet No. 5 of the Charleston Museum. Since that time, I have examined four more specimens of this rare stomatopod, three from Charleston Harbor and one from Beaufort, N. C.

In color all the fresh specimens agree with the description published in Leaflet No. 5. All agree in having the lateral process of the first exposed thoracic segment spatuliform, and in having 5 teeth on the dactylus of the raptorial claw. In all specimens the median spine of the telson is much longer than in the closely related form *C. empusa*. A table of comparative measures of the specimens examined follows:

	TOTAL LENGTH	LENGTH CARAPACE	MEDIAN SPINE OF TELSON	EYES	
				Corneal Axis	Peduncular Axis
	mm.	mm.	mm.	mm.	mm.
Chas. Mus. No. 4463.....	63	16	2.5	4	4
Chas. Mus. No. 33.355.....	115	26	2	5	5
Chas. Mus. No. 34.340.1.....	92	22.5	3	5—	4.5
Chas. Mus. No. 34.340.2 (In U. S. N. M.).....	70	18	2	4	4
Beaufort Specimen.....	117	30	2	5	5

Two recent specimens (taken November 14, 1934) from just outside the north jetty of Charleston Harbor were taken on mud bottom in about 15-18 feet of water. The Beaufort specimen was found in a jar with two other stomatopods labelled "Squilla *empusa*." There were no further data with these specimens but it is safe to assume that they were taken near Beaufort, N. C. In the U. S. National Museum, I examined some 50 lots comprising over 80 specimens of *Chloridella empusa*, with which *neglecta* might have been confused. I did not find a single specimen of *C. neglecta*. The National Museum now has one of the specimens from off Charleston Harbor, S. C., taken November 14, 1934.



Figs. 1-6. Outline drawings of the raptorial dactyli of:

1. *Gonodactylus oerstedii* Hansen
2. *Lysiosquilla excavatrix* Brooks
3. *Lysiosquilla scabricauda* (Lamarck)
4. *Chloridella neglecta* (Gibbes)
5. *Chloridella dubia* (M. Edwards)
6. *Chloridella empusa* (Say)

All actual size.

***Chloridella dubia* (M. Edwards)**

*Squilla dubia* Milne Edwards, Hist. Nat. Crust. 2: 522. 1837.

*Diagnostic characters:* Dactylus of raptorial claw bears six spines; the proximal spine is poorly developed. The eyes of *dubia* are small. The average measurements of five specimens are as follows: Corneal axis —4 mm.; axis of eye and stalk —5 mm. The median carina of the carapace is not bifurcate. The median spine on the telson is blunt. The lateral processes of the first exposed thoracic segment are bifurcate; the uppermost portion is blunt and often is not recurved as in *empusa*.

*Remarks:* The Charleston Museum has a number of specimens of this species, and although it occurs regularly at Charleston, it is by no means abundant. On the east coast of America *C. dubia* is known to range southward from South Carolina to Brazil, including the West Indies. On the west coast, there are specimens in the United States National Museum from El Salvador, Costa Rica, Ecuador, and Peru.

***Chloridella empusa* (Say)**

*Squilla empusa* Say, Jour. Acad. Nat. Sci. Phila. 1: 250. 1818.

*Diagnostic characters:* The dactylus of the raptorial claw bears six well developed teeth. The eyes are large. The average measurements of ten specimens are as follows: Corneal axis —5.6 mm.; axis of eye and stalk —5.6 mm. The median carina of the carapace is bifurcate at its anterior end. The median spine on the telson is short. The lateral processes of the first exposed thoracic segment are bifurcate and the uppermost part is elongated into a spine which recurses forward.

*Remarks:* This is the common stomatopod found in abundance in both North and South Carolina. It ranges from Massachusetts to Texas. It is also reported from West Africa.

On the coast of North Carolina, *C. empusa* is known to the fishermen by the common name "Salt-water Crawfish." Around Charleston, S. C., it is sometimes referred to as "Shrimp Mammy." This name, however, also applies to the squid *Loligo*.

A specimen which was kept for some time in a marine aquarium contributes some interesting data for a few notes. This specimen fed exclusively on shrimp and would not eat dried fish food, shredded fish, or oyster. It would eat about two small shrimp a day. Swimming rapidly, it would attack the shrimp from above, pin it down, and then grasp it with the raptorial claws. It appeared to have no trouble biting through the integument of the shrimp. The *empusa* spent much of its time swimming around the aquarium. On numerous occasions it would

swim close to the surface and roll its back out of the water, in the manner of a "porpoise." Twice in two months it shed its skin.

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NOTES ON THE OCCURRENCE OF A WHALE SHARK  
(RHINEODON TYPUS)

IN THE CAPE FEAR RIVER, NEAR SOUTHPORT, N. C.

By H. H. BRIMLEY

PLATE 46

In the early afternoon of Wednesday, June 6, 1934, a wire was received from Louis T. Moore, secretary of the Wilmington, N. C., Chamber of Commerce, to the effect that a fifty-foot whale was ashore near the Quarantine Station, Southport Harbor, and that it was ours for the asking.

On reaching Wilmington the next morning we got in touch with Mr. R. C. Fergus, who operates a large fish-dealing establishment in Wilmington, and with him, we found the tail and one of the claspers of the animal that had been removed from the body by Mr. Fergus the day before for exhibition at Carolina Beach. That morning, however, their removal to the garbage dump had been ordered by the health authorities. Hence, the photograph of a shark's tail among a scattering growth of native grasses and scrub pines.

Definite identification was simple. The sandpaper-like surface of the skin, the heterocercal tail, with its white spots, the side keels of the caudle peduncle, together with the enormous size of the tail, indicated that nothing but a large whale shark could have carried such an organ.

The thin posterior edge of the caudal had become partially dried out during its twenty hours or more exposure to a warm wind, thus pulling the lobes closer together, and I feel sure that Mr. Fergus' measurement of 9 feet, 10 inches between the tips of the lobes, made the day before, is approximately correct, my measurement of the partially dried tail being 9 feet, 5 inches.

The tail had been severed from the body at the smallest part of the caudal peduncle, immediately forward of the base of the lobes. Measured from the center of that cut in a straight line, the upper lobe showed a length of 8 feet, 1 inch; the lower lobe, measured in a similar manner, being 4 feet, 9 inches in length. From the center of the cut to the near-

est point in the concave curve of the rear edge of the caudal fin, 2 feet, 9 inches. The diameter of the several vertebra was 3 inches, and the superficial area of the caudal fin was about 18 square feet.

The cut through the caudal peduncle, made at its smallest cross section, was 13 inches wide by 10 inches deep. The lower edge of the tail was white for perhaps two feet from the base, and a trace of yellow showed on the keel.

Some shrinkage, in addition to that estimated for the measurement between the tips of the lobes, had undoubtedly taken place. I believe that the measurements of the section through the caudal peduncle would have been as much as 14 by 11 inches when the cut was made about 20 hours previously and that the lobes might each have been from 1 to 2 inches longer if measured when the tail was freshly cut.

The single clasper that had been saved along with the caudal fin measured 24 inches in length by  $4\frac{1}{2}$  inches in average diameter, with little or no taper. It showed no color other than white.

The spots on the tail were irregular, both in their distribution and in shape, the largest measuring 1 inch by  $1\frac{1}{2}$  inches. Their outlines were not sharply defined. On one side of the tail, about 12 inches from the tip of the upper lobe, a group of spots ran together in an irregular line about 6 inches in length.

Mr. Fergus, whose statements were confirmed by a colored fisherman who was aboard the boat with him when visiting the specimen the day before, gave us the following additional particulars:

Estimate of total length, 40 feet.

The body was submerged on a shoal in the Cape Fear River approximately  $3\frac{1}{2}$  miles above the town of Southport, and not on the river beach. An effort was made by Mr. Fergus to drag the body off the shoal, and beach it for exhibition purposes, but without success. It seemed to be either bedded down, or to possess so high a specific gravity as to be beyond the power of a small gas boat to move, and it also seemed to be firmly anchored against the pull of the tides. Only the upper part of the first dorsal was exposed above the surface.

The spots on the back were described as white, the largest approximating 3 inches in diameter. A convenient metal cap of a Mason fruit jar was used in indicating their apparent size. The spots seemed to gradually decrease in size down the side of the body.

The color of the back was described as "slaty." Perhaps slaty brown, or brownish slate might be more descriptive of the general color of the upper part of the tail as we saw it.

The most noticeable feature of this find is the occurrence of a whale shark so far north of all previous records on the Atlantic coast of the United States. Previous to this, the most northern Atlantic point from which the species has been recorded was Ormond Beach, Florida, in 1902, Ormond being some three hundred and fifty miles south of the mouth of the Cape Fear River, which is in latitude approximating  $34^{\circ}$  N. The most northern Pacific record for the species is Cape Inubo, Japan, in latitude  $35^{\circ} 39'$  N. According to Dr. E. W. Gudger, this is the seventy-eighth recorded specimen, the seventy-seventh having been recorded by him recently from Acapulco, Mexico.

The Gulf Stream is probably responsible for carrying this great fish so far north of the previously known northern limit of the species on the west side of the Atlantic.

Two deep cuts in the side of the body, probably resulting from contact with a vessel's propeller, appeared to be the cause of the animal's death.

STATE MUSEUM,  
RALEIGH, N. C.

PLATE 46





# THE PERFECT STAGE OF A LEAFSPOT FUNGUS ON RED MULBERRY

By FREDERICK A. WOLF

PLATES 47 AND 48

In connection with a survey of the diseases of trees in the Duke Forest, Durham, N. C., the writer encountered one that involves the foliage of red mulberry, *Morus rubra* L. This disease appears, from records of collections and exsiccati, to be of common occurrence in the eastern United States and throughout many of the countries of Europe. The causal fungus is generally regarded as one of the pycnidial fungi, *Phleospora Mori* (Lév.) Sacc. A study of its morphology, however, shows that its structural characteristics accord more nearly with those of the genus *Cercosporella*. In addition, it has been found that the ascigerous stage develops, in spring, in the old lesions of decaying leaves. The present report, therefore, deals briefly with the writer's observations on the morphology and taxonomy of the pathogen.

## CONIDIAL STAGE

The disease can be recognized by the presence of a few to many, circular, brown spots on all of the foliage. The lesions on drying become fuscous to ochraceous, and have a broad, dark brown border (pl. 47). Conidia are formed on both leaf surfaces but are most abundant on the lower surface. They may form in gelatinous masses in such abundance that on drying they appear as a pinkish incrustation. The conidia are cylindrical, curved, blunt-pointed, hyaline, many-septate, and are provided with oil droplets (pl. 48, A). They vary in size from 20 to  $60 \times 5$  to  $8\mu$ . The conidiophores form fascicles that project approximately  $10\mu$  above the leaf surface (pl. 48, C).

Apparently this fungus was first named *Fusarium maculans* Beréng. (*Atti Congr. Mil.* 1844), in 1844. A more complete account of it was given two years later by Léveillé<sup>1</sup> under the name *Septoria Mori* n.sp., in which account he states "Tres petite especé, dont la présence est

<sup>1</sup> Léveillé, J. H. Description des champignons de l'Herbier du Museum de Paris. *Ann. Sci. Nat. Bot.* 5: 249-304. 1846.

annoncé sur les faces des feuilles par un grand nombre de taches brunes. . . . les spores, linaires, simples, mêlées, avec une matière gelatineuse, forment en sortant un filet très court et blanc. Quand elle existe sur un arbre elle affecte presque toutes les feuilles, et en cause promptement le desséchement et la chute."

In 1884, Saccardo<sup>2</sup> employed the name *Phleospora Mori* (Lév.) Sacc. and assigned to synonymy *Septoria Mori* Lév., *Fusarium maculans* Beréng., and *Fusisporium Mori* Mont. (Bull. Soc. Agr., 1853). The writer is at a loss to know how Léveillé and Saccardo could have interpreted any structures possessed by this fungus as pycnidia, but it may be that they regarded the leaf glands as conidial conceptacles.

It also appears highly probable that *Phleospora moricola* (Pass.) Sacc. (*Septoria moricola* Pass.) is identical with the fungus under consideration. Saccardo<sup>3</sup> indicated that such might be the case in his query "An ejusdem forma peculiaris autumnalis?" Collections made in early summer, in North Carolina, have less robust conidia with fewer septations than those collected in late summer or in autumn, thus indicating that *P. moricola* may be an autumnal form of *P. Mori*.

#### PERITHECIAL STAGE

Leaves bearing the conidial stage were collected in September, 1933, and stored out of doors at Cambridge, Mass., during the following winter. By May, 1934, black perithecia were abundantly present on the upper leaf surface of the old lesions. These perithecia ranged in diameter from 60 to 80 $\mu$  and were quite superficial, the basal portion only being sunken within the leaf tissues (pl. 48, D). The asci are clavate, fasciculate, aparaphysate, 35 to 40 x 5.5 to 6.5 $\mu$  (pl. 48, 1). The ascospores are 12 to 15 x 3.5 to 4 $\mu$  (pl. 48, E).

Cultures, originating from ascospores, were made by permitting the ascospores to be discharged on inverted agar plates. Conidia were not developed on the resultant growth but the colonies had the appearance of colonies isolated from conidia. Unfortunately proof of the genetic connection of the perithecial and conidial stages was not established because mulberry trees were not available for inoculation experiments. Evidence of connection, therefore, rests upon the presence of perithecia within old conidial lesions, upon the similarity of cultures isolated from conidia and from ascospores, and upon the fact that the connection of

<sup>2</sup> Saccardo, P. A. *Sylloge Fungorum* 3: 577. 1884.

<sup>3</sup> Saccardo, P. A. *Sylloge Fungorum* 3: 578. 1884.

certain other fungi bearing similar conidial and perithecial stages has been established.

#### TAXONOMY

The perithecial stage of the pathogen on mulberry is manifestly a species of *Mycosphaerella* (*Sphaerella*). At least three species of this genus have been listed to occur on mulberry, namely *Sphaerella mori-albae* Cke., *S. morifolia* Pass., and *S. Mori* Fkl. The fungus under consideration is clearly distinct from the first two of these species. It may, however, be identical with *Sphaerella Mori*. Saccardo<sup>4</sup> was inclined to this opinion, as is indicated by his statement "Spermogonium *Septoria Mori* Lév. sistit," although he was not able to establish proof. He points out, furthermore, that no one seems ever to have seen the ascigerous stage nor has he himself come upon a description of it ("Statum vero ascophorum nullibi observare nec descriptum invenire mihi contigit"). Specimens collected by Auserwald and identified as *Sphaerella Mori* Fkl. were found by Saccardo<sup>4</sup> to be *Phyllosticta osteosporam* Sacc. In spite of the uncertainty of the identity of *Sphaerella Mori*, in the mind of Saccardo, and of the inadequacy of Fuckel's description of this fungus it seems reasonable to regard the pathogen on mulberry as *Mycosphaerella Mori* (Fkl.), and to emend its description according to the present findings.

***Mycosphaerella Mori* (Fkl.) emend.** (Symb. Myc. 1: 106. 1869).

Syn. *Fusarium maculans* Beréng. Atti Cong. Mil. 1844.

*Septoria Mori* Lév. Ann. Sci. Nat. Bot. 5: 279. 1846.

*Fusisporium Mori* Mont. Bull. Soc. Agr., 1853.

*Phleospora Mori* (Lév.) Sacc. Syll. Fung. 3: 577. 1884.

*Cercosporella maculans* (Beréng.) n. comb.

?*Septoria moricola* Pass. Myc. Univ. n. 384.

?*Phleospora moricola* (Pass.) Sacc. Syll. Fung. 3: 578. 1884.

Peritheciis gregariis, epiphyllis, minutis, sphaeroideis, erumpenti-superficialibus, membranaceis, fuscis, apice pertusis,  $60-80\mu$  diam.; ascis basi fasciculatis, clavatis, aparamphysatis, apice rotundatis, 8-sporis,  $35-40 \times 5.5-6.5\mu$ ; sporidiis subdistichis, curvulis, 1-septatis, ad septum constrictis, haud v. paullo inaequalibus, loculo superiore paullo crassiore,  $12-14 \times 3.5-4\mu$ .

Hab. in foliis morientibus et putridis Mori sps. in Brittania, Gallia, Italia, Germania, Austria inf. et Amer. bor.

Status conidicus—Statum conidicum *Cercosporella* sistit. Maculis

<sup>4</sup> Saccardo, P. A. Sylloge Fungorum 1: 536. 1882.

singulis v. paucis in quoque folio, orbicularibus, 2-6 mm. diam., centro expallentibus, brunneo-marginatis; caespitulis amphigenis plerumque hypophyllis, pallide subcarnosulis; conidiophoris stomate oriundis, brevibus, hyalinis; conidiis vermicularibus, 3-10-septatis, ad septa constrictis utrinque obtusulis, crassatulis, guttulatis, hyalinis, 20-60 x 5-8 $\mu$ .

Hab. ad folia viva Mori sps.

Specimens bearing perithecia and others bearing conidia have been deposited in the Farlow Herbarium, Harvard University, Cambridge, Mass.

Acknowledgment is gladly made of the help given by D. H. Linder, G. D. Darker, and W. W. Diehl.

#### SUMMARY

This report is concerned with the morphology of a common leafspot fungus of mulberry. It possesses a conidial stage that is commonly designated *Phleospora Mori* (Lév.) Sacc. and that appears properly to belong to the genus *Cercospora*. An ascigerous stage develops in spring on fallen leaves. This stage seems to be identical with *Sphaerella Mori* Fkl., an inadequately described form that was suspected by Sarcardo of being connected with *Phleospora Mori* (Lév.) Sacc. (*Septoria Mori* Lév.). The pathogen is herein described and illustrated.

BOTANY DEPARTMENT,  
DUKE UNIVERSITY,  
DURHAM, N. C.

PLATE 47



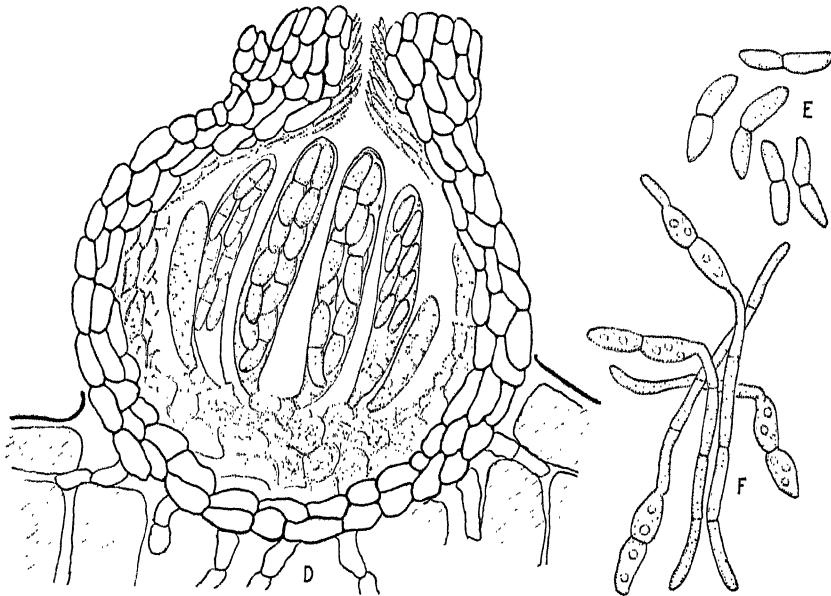
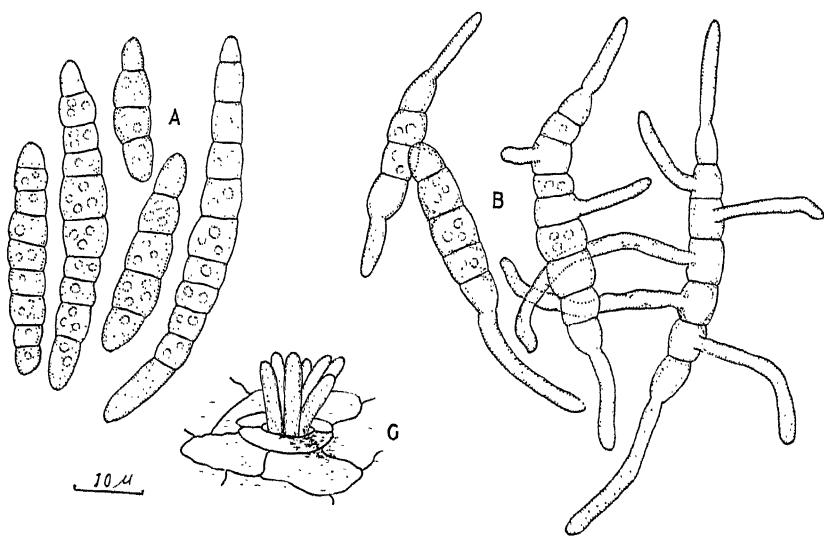
LEAVES OF RED MULBERRY, SHOWING LESIONS PRODUCED BY THE CONIDIAL  
STAGE OF *MYCOSPHAERELLA MORI*

Lower leaf surface shown by the outer leaves and upper surface by the  
middle leaf

#### EXPLANATION OF PLATE 48

- A. Conidia of the *Cereospharella* stage.
- B. Conidiophores.
- C. Germinating conidia.
- D. Perithecium of *Mycosphaerella Mori* in vertical section.
- E. Ascospores that were forcibly expelled onto a slide placed above the ostioles.
- F. Germinating ascospores.

PLATE 48





## A NEW SPECIES OF KEITHIA ON RED CEDAR<sup>1</sup>

By J. K. MILLER

### PLATE 49

During the summer of 1934, the writer collected in the Duke Forest, near Durham, North Carolina, a discomyctetous fungus that occurs upon the leaves of red cedar, *Juniperus virginiana* L. This fungus was found to belong to the genus *Keithia* and to differ in certain important features from the other species of this genus that have previously been reported to attack gymnosperms. It was, therefore, decided to make a study of its morphology and development.

#### HISTORICAL

Four species of *Keithia* have previously been described, all of which occur on gymnosperms. The genus is based upon a fungus that, in 1880, was first given the name *Phacidium tetrasporum* Phillips and Keith. This fungus was collected in Scotland by the Rev. J. Keith (5) where it was found to be parasitic upon the leaves of common cedar or juniper, *Juniperus communis* L. In 1892, Saccardo erected the genus *Keithia* (7) with *Phacidium tetrasporum* as the type.

Dr. W. G. Farlow (4), in 1884, described as *Stictis tsugae*, a fungus that he found during the summer of 1883, on hemlock, *Tsuga canadensis* Carr., in New Hampshire. This fungus was referred by Saccardo (6), in 1889, to *Propolidium tsugae*, but Dr. E. J. Durand (3), in 1913, changed it to *Keithia tsugae*, with Farlow as the authority for the change.

During 1908 and 1909, Dr. J. J. Davis (2) collected, in Wisconsin, on the leaves of American arbor vitae, *Thuja occidentalis* L., another member of the genus *Keithia*. These collections were sent to Durand and he regarded the fungus as *K. thujina* but did not describe it until 1913 (3).

In the summer of 1915, Professor R. A. Harper and Dr. B. O. Dodge collected, in New Jersey, on living leaves of *Chamaecyparis thyoides* (L.) B.S.P. another member of the genus *Keithia*. These collections were

<sup>1</sup> From a thesis submitted in partial fulfilment of the requirements for the Master of Arts degree at Duke University. Acknowledgment is made of assistance given by Dr. F. A. Wolf.

sent to Dr. J. F. Adams (1) and he described it and affixed the name *K. chamaecyparissii*.

#### APPEARANCE OF THE KEITHIA DISEASE ON RED CEDAR

This disease may be found to involve only a small portion of the leaves or it may be very abundant. It can be recognized by the presence of black apothecia, the fruiting structures of the causal fungus, that project prominently above the leaf surface. Usually a single apothecium only occurs on each diseased leaf although as many as three have been noted, all occurring on the morphological lower surface. The fungus may cause the death of the leaves so that they eventually become dry and brown. Infected leaves are not shed prematurely but persist as long as normal leaves of the same age. The apothecia instead of falling away after the discharge of the ascospores, remain attached to the leaf indefinitely. They disintegrate together with the leaves, and their weathered remains can be recognized even on the fallen leaves.

The observations that have thus far been made do not warrant a definite statement as to the economic importance of this *Keithia* disease. It apparently does not involve a large proportion of the cedars within the Duke Forest. Groups of affected trees have been found throughout the area, and those so affected show a marked lack of vigor. The disease, in the writer's opinion, is of potentially serious consequence to the growth of red cedar as a forest and ornamental tree in the area around Durham, North Carolina.

#### MORPHOLOGY OF THE FUNGUS

A study of the development of the fungus was facilitated by examination of material collected at different times throughout the summer and by the use of sections of infected leaves that had been appropriately killed, embedded in paraffin, and sectioned. By crushing and teasing apart the developing apothecia and by examining paraffin sections of infected leaves bearing apothecia one finds (1) that the vegetative parts of the fungus are intercellular (fig. 2); (2) that a compact brown fungoid stroma forms immediately beneath the epidermis and above the palisade parenchyma; (3) that the apothecium arises from this stroma, and the epidermis is ruptured by the developing apothecium; (4) that the epidermis does not persist as a flap or fold over the surface of the apothecium; (5) that the young apothecium is at first a cushion-shaped mass of fungoid parenchyma tissue, visible only with the aid of a hand lens. At this stage the leaves are not discolored but are entirely green; (6)

that apothecia are mature 5 to 8 weeks after inoculation. At this stage when viewed in vertical section they are hemispherical with a broad short stalk (fig. 1). In outline they are circular to oval and their consistency is carbonaceous. The surface is convoluted and rugose. Mature apothecia vary in height from 300-400 $\mu$  and in diameter from 400-525 $\mu$  (fig. 1). The outer surface of the excipulum consists of a compact layer that ruptures by irregular fissures to permit discharge of ascospores. It consists of brown fungoid cells that appear distinctly black until they have been separated and examined under the microscope. The inside of the apothecium is completely filled with asci and paraphyses that arise from a well developed hypothecium. At first the asci are hyaline but as the eight spores are cut out the entire ascus and contents begin to turn brown. At maturity the asci measure 40-50 x 80-90 $\mu$  (fig. 4). The wall of the asci consists of a double layer, a thin inner one and a thick outer one that is thinner at the apex. Preparatory to the discharge of ascospores the outer wall ruptures at the thinner apical portion and the inner wall then elongates. In this condition the ascus (fig. 5) will measure 130-135 x 35-40 $\mu$  and the individual ascospores are more easily seen, due to their change in arrangement within the ascus.

The ascospores are hyaline at first but become brown at maturity. They are two-celled and very unequal, the distal cell always being the larger. Mature ascospores range in size from 28-30 x 15-18 $\mu$  (fig. 6). They are forcibly expelled as shown by the fact that they have been allowed to collect on agar in inverted petri dishes. Discharge was accomplished by placing infected cedar leaves on moist paper with the apothecia directed upward. Apparently the ascospores are discharged singly as shown by the presence of groups of eight ascospores on the agar, each spore being separate from the others.

The paraphyses are numerous and are at first hyaline and entire, becoming segmented and brown at maturity. They are slightly longer than the asci, often branched at the distal end. The distal end is 3.5-4 $\mu$  in diameter, the proximal end, 2-3 $\mu$  in diameter (fig. 3).

#### GERMINATION

Attempts have been made to germinate ascospores on the surface of potato agar and in drops of water on slides placed in moist chambers. In most cases no germination whatsoever followed. In a few cases, however, after 24 hours in drops of water or on the surface of agar plates, short germ tubes developed. Germination may occur from either cell

of the ascospore, however the smaller cell will usually germinate first. Apparently growth ceases soon after the germ tube appears.

#### TAXONOMY OF THE FUNGUS

Two of the known species of *Keithia* are 2-spored, two, 4-spored. If the genus be amended to include 8-spored forms, a change which appears to be in accord with results of investigation of nuclear phenomena and spore formation in certain other ascomycetes, then the fungus under consideration is a species of *Keithia*.

Since no species of *Keithia* with 8 spores has been described and since this 8-spored species occurs on *Juniperus*, it is assigned the specific name *juniperi*. A brief summary of the characteristics of the new species follows:

##### *Keithia juniperi* n. sp.

Hypophyllous, subepidermal at first, erumpent, slightly elevated and cushion-like, black, circular-ovate, height 300-400 $\mu$  and diameter 400 x 525 $\mu$  at maturity, excipulum dark. Ascii hyaline at first, olive brown at maturity, broadly ovate, 40-50 x 80-90 $\mu$ , 8-spored. Ascospores hyaline and continuous at first, olive brown and two-celled at maturity, 15-18 x 28-30 $\mu$ , cells very unequal, distal end always the larger. Paraphyses numerous, slightly longer than ascii, apex clavate, hyaline and continuous at first, olive brown and septate at maturity, apex 3.5-4 $\mu$  in diameter, base 2-3 $\mu$  in diameter.

Ascomata hypophyllia innata, deinde crumpentia, pulvinata, atra, orbicularia vel ovata, 300-400 $\mu$ , atra, 400-525 $\mu$  lata.

Asci ovati, brunnei, 40-50 x 80-90 $\mu$ , octispori. Sporae brunneo-olivascentes, 15-18 x 28-30 $\mu$ , septa ad apicem posteriorem inaequaliter divisae.

Paraphyses furcatae, clavato-incrassatae, ad apicem 3.5-4 $\mu$  diam., ad basem 2-3 $\mu$  diam.

Hab. in foliis vivis *Juniperi virginianae*.

For the convenience of mycologists, type specimens have been deposited in the Farlow Herbarium, Harvard University, Cambridge, Mass., in the New York Botanical Garden, New York, N. Y., in the Herbarium of the Department of Plant Pathology, Cornell University, Ithaca, N. Y., and in the Herbarium of the New York State Museum, Albany, N. Y.

#### SUMMARY

This report deals with a new species of *Keithia* that is parasitic on red cedar. Affected trees are lacking in vigor. The disease can be recognized by the presence of black apothecia on the lower leaf surface.

The morphology of the pathogen on cedar is quite like other known species of *Keithia*, except that it has eight spores. Two of the other species of *Keithia* are 2-spored and two are 4-spored.

The fungus is herein briefly described as *Keithia juniperi*, n. sp.

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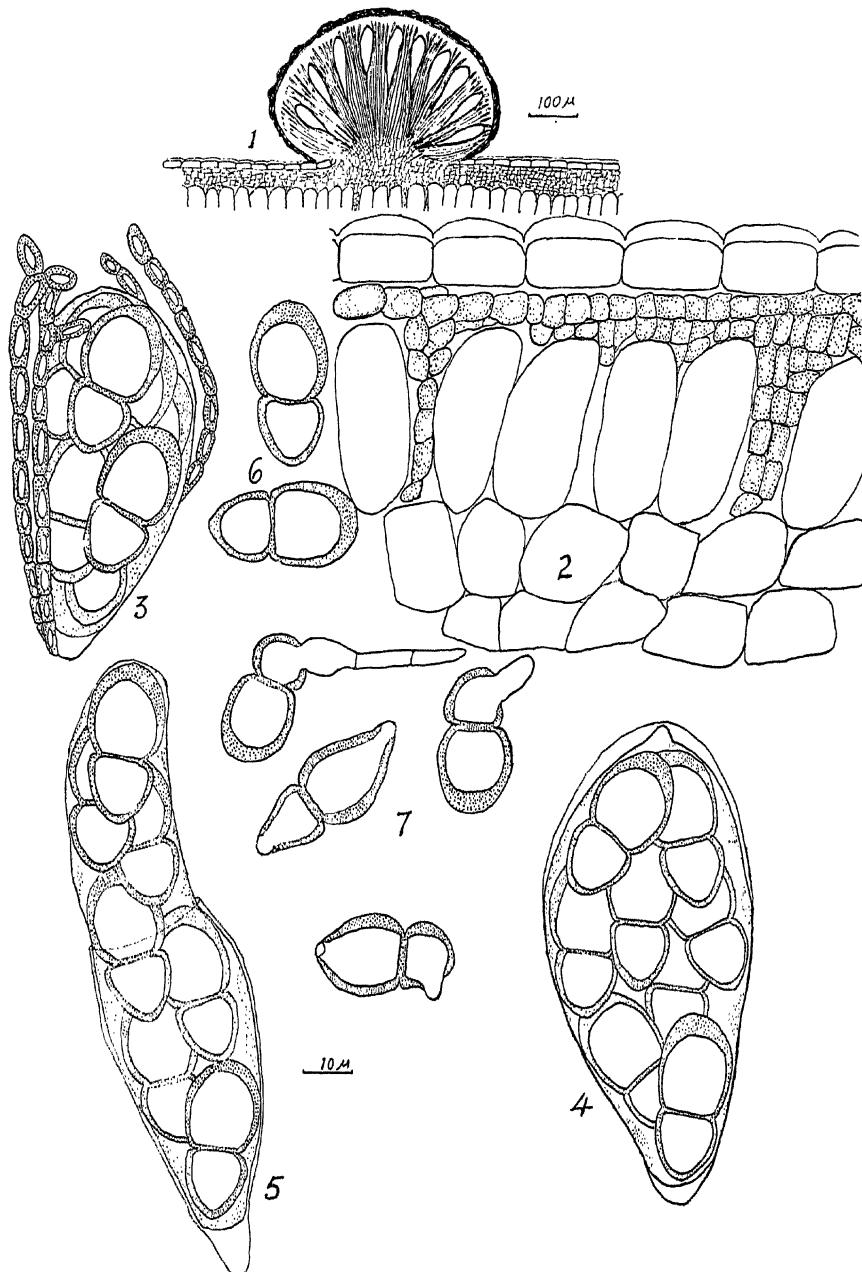
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## EXPLANATION OF PLATE 49

*Keithia juniperi* n. sp.

- Fig. 1. Microtome section of apothecium on host tissue.
- Fig. 2. Host tissue permeated from fungoid cells.
- Fig. 3. Mature ascus with ascospores and paraphyses.
- Fig. 4. Mature ascus and ascospores.
- Fig. 5. Mature ascus with outer wall ruptured, before spore discharge.
- Fig. 6. Mature ascospores.
- Fig. 7. Stages in the process of germination of ascospores.

PLATE 49





## CAVITY-DEVELOPMENT AND SPORE-FORMATION IN PISOLITHUS TINCTORIUS

By CAROLINE A. LANDER

### PLATES 50 AND 51

*Pisolithus tinctorius* Pers. has been known under a number of names as *P. arenarius* A. and S., *Polysaccum pisocarpium* Fr., and *Polysaccum crassipes* D.C. Coker and Couch (2) using Persoon's Synopsis Fungorum as a starting point for Gasteromycetes, accepted *Pisolithus tinctorius* and were supported in their acceptance by Fischer in Engler and Prantl (3). Tulasne (11) in 1842 described the species and gave a short account of its gross morphology.

Bruns (1), in 1874, distinguished the three types of hyphae in the rhizomorph and stalk, the specific type in the tramal plate, and the fertile hyphae with clamp connections in the cavities. He noted that the peridium is made up of hyphae which surround the peripheral cavities in contrast with the specially formed complex structure in *Scleroderma*; that the capillitium is lacking; and that development and maturation of the cavities is progressive. The base of the fruiting body is composed of a confused network of hyphae. Above this is a layer in which the first indication of cavities is noticeable because of the swelling and darkening of the hyphae in indistinct, limited groups. Next is the region of definite cavities and of the tramal plates which surround the cavities. The cavities contain branching hyphae, the tips of which swell to form the basidia. At the top of the fruiting body peridioles with mature spores are shed by the disintegration of the peridium. Progressive formation of the cavities from the upper stalk region continues for some time.

Lohwag (7) separated *Pisolithus* from *Scleroderma* because of the difference in their peridia, and because of the progressive development and maturation of the cavities in *Pisolithus*. Coker and Couch (2) mentioned the abundance of the black jelly containing a yellow pigment between the peridioles and hyphae of the peridium, and purple pigment in the spores; also the fact that the spores increase in size after leaving the basidium.

No record of a cytological study of *Pisolithus* has been found in the literature. Fusion of the two nuclei in the basidium in the spireme stage has been reported for two related forms, *Nidularia* (Fries, 4) and *Hydnangium* (Petri, 9). Fries made a detailed study of the synaptic stages of the fusion nucleus; of the two divisions; and of the passage of the nuclei into the spores. A similar account has been given for *Scleroderma lycoperdooides* (Lander, 6).

Maire (8) described the presence and action of centrosomes in the division of the nuclei in the basidium of several species of Gasteromycetes.

#### MATERIAL

The material of *Pisolithus tinctorius* Pers. was collected during August, 1933, at Chapel Hill, North Carolina. It was found on well-drained gravel and sandy soil, in old fields, and in waste places. The fruiting bodies were killed in formalin-acetic-alcohol, Flemming's medium, or chrom-acetic solutions. The material was allowed to remain in 70% alcohol for six months with frequent changes in order to dissolve the pigments. The triple stain gave the best results for cytological study, and Haidenhain's iron-alum-haematoxylin with fast green as a counter-stain was best for differentiating hyphae.

#### OBSERVATIONS

##### *Cavity-development*

Representative stages in development of the fruiting body of *Pisolithus tinctorius* were studied from an immature stage one-half inch in diameter to that of a mature body shedding peridioles. Very young stages were not found. However, the development takes place progressively and regions of the youngest forms studied showed cavity differentiation, the lower part being homogeneous throughout.

The basal region is composed of a confused network of narrow thin-walled hyphae. It is fairly compact, with few spaces between the filaments. The hyphae, all of which are similar in appearance, are interwoven in an irregular manner. The hyphae contain hemispherical pads at the cross walls; have occasional clamp connections; are sparsely branched, and are composed of long binucleate cells.

With development, this compact region of tangled hyphae expands and the hyphae become looser in arrangement. Scattered irregularly throughout this region are portions of hyphae which become particularly loose, so much so that spaces appear between the hyphae. In the

regions of the lighter areas the hyphae begin to differentiate. This is earliest manifest in the greater density of protoplasm and in the increased diameter of the cells.

There follows a rapid increase in the differentiation of the hyphae. They divide rapidly forming short cells which are as broad as long. These cells are binucleate, have a strong affinity for fast green stain, and contain on their cross-walls very prominent hemispherical pads. The pads are extremely large and absorb safranin stain most rapidly.

The hyphal filaments branch frequently and these in turn rebranch. The branches are short, often not over three or four cells in length. Thus there is in each cavity primordium a main axis or central group of three or four long filaments with many short branches giving the hyphae a tufted or feather like appearance.

A number of these primordia of fertile branches are formed. At first these have no definite arrangement and are massed into a confused, irregular group (fig. 27). In contrast to the original fundamental hyphae, the filaments are not interwoven and are looser in arrangement. A group of such tufted branches is the earliest indication of a cavity. These are the hyphae from which the basidia will arise later and which will fill the fertile cavity. In the stage just described the cavity has no definite boundary or shape.

After the first differentiation of hyphae, the number of groups of basidial primordia increases. Along with the increase goes a continued development in size and number of branches of the individual filaments. The main axes assume a radial direction and grow toward the center of the cavity.

There is no indication of the original fundamental hyphae in the cavity. Early in the process of differentiation they disappear from the region. They become organized in the tramal plates surrounding the cavities. In contrast to *Lycoperdon* (Lander, 5; Swartz, 10) there seems to be very little tearing of the fundamental tissue in the cavity-formation. Instead, the disappearance of the fundamental hyphae from the cavities is brought about by the change of position of the filaments caused by the growth and expansion of the fruiting body; and by a differentiation of many of the hyphae of the region into fertile primordia.

After the first hyphal differentiation the cavities have a definite size and shape, tending to be spherical (fig. 28). They are bounded by the tramal plates in an even contour, and are compactly and completely filled with the hyphal branches of the fertile primordia. The tip cells

of the short lateral and secondary branches appear swollen; prominent hemispherical pads are present on the majority of the cross-walls; and clamp connections are abundant (fig. 1).

The cavities increase in size and become more regular in shape. The expanse is general in all directions involving the growth and rearrangement of the tramal hyphae as well. The tramal plates assume the typical compact appearance with the majority of the hyphae, making up each plate, parallel to each other and with their lateral walls appressed. A few long filaments, main axes of the basidial primordial groups, radiate toward the center of the cavity, each with abundant short lateral branches (fig. 29).

The tip cells of such branches become greatly swollen and are the basidial primordia. These cells ultimately increase to five times their original size. Clamp connections may be present even on the basal wall of a basidium (fig. 1).

Four spores occur regularly on a basidium. Though in some cases five may be formed, only four develop. The spores have attained about three fourths of their mature size and in many cases their walls have become roughened before they are freed from the basidium. Growth of the spores seems to continue a short time after the collapse of the basidium.

The cavity now has a definite spherical character. It is filled with the crowded mass of spores. The basidia have disintegrated, with the exception of a few near the outer margin of the cavity; and a few scattered filaments of the hyphal branches remain (fig. 30). The tramal plates have become very thin in proportion to the enlarged cavities. Tramal hyphae are thick-walled and compactly pressed together (fig. 29).

A pigmented jelly fills the tramal spaces and the cavity surrounding the spores. The jelly contains a yellow pigment in such abundance that it is most difficult to distinguish cells. The mature spores contain a purple pigment.

At maturity the tramal plates split, their hyphae nearest the cavity form a brittle layer around the cavity making the peridioles. The peridioles, the gritty particles in the fruiting body, are later freed by the breaking of the thin peridium.

The maturing and freeing of the peridioles take place by degrees so that disintegration may be seen in an upper layer while the lower cavities are beginning to develop.

*Spore-formation*

All the cells of a young fruiting body are binucleate. In a basidial primordium the two nuclei lie close together. The enlargement of the cell is accompanied by an increase in nuclear size. At the time of fusion the nuclei are approximately three times as large in diameter as when first observed.

These nuclei move toward each other and lie in close proximity for a short time (fig. 3). The nuclear reticulum is thickened and becomes irregular. In it more darkly stained portions may be identified. The irregularity and density of the reticulum increase as the nuclei approach each other. The chromatic material of each nucleus tends toward the side nearest the other nucleus (figs. 3, 4). The prominent nucleolus may retain a central position or may migrate to one side.

As the nuclei come together they become flattened in the plane of contact (fig. 4). The reticula are flattened against the appressed nuclear membranes. The membranes disintegrate and the two reticular masses intermingle (fig. 5). A number of examples of such a stage were found. The fusion nucleus is long in proportion to its width, retaining somewhat the shape of two nuclei before fusion; two nucleoli are prominent; and one chromatic reticulum is present. Later only one nucleolus is distinguishable and the nucleus is spherical (fig. 6).

A definite spireme before and at the time of fusion such as Fries (4) reported for *Nidularia* and Petri (9) for *Hydnangium* could not be distinguished.

The fusion nucleus,  $2.5\text{--}3\mu$  in diameter, lies in the apical portion of the swollen basidium. It contains a large nucleolus, around which is a clear space, at least in fixed material. Throughout the rest of the nuclear cavity, however, is a reticulum in which more darkly stained portions may be distinguished (fig. 6). The reticulum becomes thickened, and forms a spireme. The spireme aggregates toward one side of the nucleus, surrounding the conspicuous nucleolus. This stage resembles synizesis, characteristic of the heterotypic prophases of higher plants (fig. 7).

The threads loosen from the synizetic condition and form an open spireme (figs. 8, 9). Later the spireme contracts and breaks into four parts (fig. 10). It could not be determined whether each of these four parts is double or four-parted.

In the next stage observed the division spindle is formed. It is a long, narrow spindle with few distinguishable fibers, lying in the apical region transversely to the longitudinal axis of the basidium. The spin-

de poles reach the walls of the basidium and at each pole is a centrosome (figs. 11, 12, 13, 14).

Four pairs of chromosomes are spread along the spindle. The pairs are sometimes separated so that they appear as eight individual chromosomes (figs. 12, 13, 14).

In a few cases, as illustrated in figure 11, four groups of chromatic bodies which may be interpreted as two pairs or as four double chromosomes are present in the center of the spindle and two chromatin fragments lie near one pole. A streaming of the chromatic material along the spindle and its breaking into fragments are frequent. It is difficult to interpret this anaphase division stage for two reasons: the chromosomes are extremely small, and fragments are common. It would seem that the separation of paired chromosomes takes place in the first division rather than, as is common in the higher plants, in the second division.

At a late telophase stage two pairs or four individual chromosomes are grouped close together at each pole (fig. 15).

Two daughter nuclei are organized. The rarity of the two-nucleate as compared with the one- and four-nucleate stages suggests that interkinesis is of short duration. The second division, occurring simultaneously in both daughter nuclei, takes place rapidly. The spindles of the second division, like that of the first, lie in the apical portion of the basidium transverse to its longitudinal axis; they make a right or oblique angle with each other (figs. 16, 17, 18, 19). The spindles are in close proximity, so that it is difficult to distinguish one from the other.

Two pairs or four single chromosomes are seen at the equatorial plate of each spindle. These separate and move to the poles (figs. 16, 17). In anaphase stages two chromosomes are clearly distinguishable at each pole (figs. 18, 19, 20). As a result of the second division four nuclei are organized.

These four nuclei move to the central and basal part of the basidium, where they remain for a short time. Small, narrow protuberances, the sterigmata, now appear at the distal end of the basidium. These outgrowths elongate, and each enlarges at its distal end; the enlargements become the spherical spores. As the spores begin to enlarge, a large vacuole is formed in the basidium below the nuclei; the increase in size of this vacuole seems to cause the nuclei to be pushed toward the apical region of the basidium.

A darkly stained body suggestive of a centrosome is visible near each of the four nuclei (fig. 21). Fiber-like strands radiate from each centrosome to the corresponding nuclei (fig. 21). The nuclei become stretched in the direction of the centrosome (fig. 24). The centrosomes move toward the sterigmata.

Changes occur in the nuclei about the time the spores have attained two-thirds their mature size and show signs of the thickening and roughening of their walls. The prominent nucleolus is no longer visible in each nucleus; the reticulum is darkly stained and contains irregular masses of darker material (figs. 23, 24). The membrane disintegrates, the reticulum condenses and is drawn out along the fibers. The chromatic material seems to be neither in the form of a definite spireme nor in that of individual chromosomes, but rather in an irregular mass on the fibers (fig. 22). This mass could be interpreted either as a twisted condensed thread or as a group of chromosomes so massed together that they are individually indistinguishable. This stage may be interpreted as preparation for the division of the nucleus following in the spore and which is completed in the spore after the passage of the fibers and chromatic material into the spore (fig. 22). Figure 25 shows the anaphase stage of division in the spore. Two chromosomes go to each pole. The mature spore is binucleate (fig. 26).

#### SUMMARY

Basidial cavities in the fruiting bodies of *Pisolithus tinctorius* arise by the differentiation of the fundamental hyphae. They are first distinguishable because of the increased diameter of the cells and their strong affinity for fast green stain.

The differentiated hyphae divide rapidly, branch and rebranch to form tufts of cells. A number of such groups radiate toward a common point, all other hyphae disappearing in the region.

By general growth of the fruiting body, and by continued differentiation large spherical cavities are formed.

The fundamental hyphae become parallel and compressed against each other surrounding the cavities to form the trama plates.

The tip cells of the branches of the differentiated hyphae increase to five times their original diameter and form basidia.

Four spores are regularly formed on each basidium.

At maturity the cavity is filled with spores, surrounded by heavy-walled tissue, and freed as a peridiole.

The differentiation and maturation progresses by degrees from the top to the base. The upper stalk region remains meristematic for some time.

An abundance of a pigmented jelly fills the cavities and the tramal hyphae.

All the cells of the fruiting body are binucleate, have hemispherical pads on their cross-walls, and occasional clamp connections.

The fusion of the two nuclei of the basidial primordium takes place while the chromatic material is in an irregular thickened reticulum.

The fusion nucleus forms a spireme and then passes through a stage suggestive of synizesis.

The spindle of the first division lies in the apical portion of the basidium transverse to its longitudinal axis. Four pairs or eight individual chromosomes spread along the spindle. A centrosome is present at each pole. In the late telophase two pairs or four individual chromosomes are grouped at each pole.

The spindles of the second division are likewise transverse to the longitudinal axis, and are in close proximity to each other or at right angles to each other.

Four chromosomes are spread along the spindle and two go to each pole.

The four nuclei formed move to the base of the basidium, but later are pushed to the apical region by a large vacuole.

After the formation of the spores the nuclei, attached by fibers to centrosomes, are pulled toward the sterigmata.

The nuclei lose their characteristic form and are carried into the spore as an irregular mass of chromatin on fibers, a stage in preparation for division which is completed later within the spore.

This research was carried on while the writer was the holder of the Sarah Berliner Research and Lecture Fellowship given by The American Association of University Women.

The writer wishes to express appreciation to Dr. E. M. Gilbert and to Dr. C. E. Allen for helpful suggestions throughout the investigation. Also to Dr. J. N. Couch for assistance in collection and identification of material.

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## EXPLANATION OF FIGURES

### PLATE 50

Fig. 1. Basidial primordia branch. Fusion of nuclei in uppermost basidium, and clamp connection at the base; hemispherical pads on the cross-walls.

Fig. 2. Binucleate basidial primordium.

Figs. 3, 4, 5. Fusion of nuclei in basidium.

Fig. 6. Fusion nucleus in basidium in spireme stage.

Fig. 7. Same in synizesis.

Figs. 8, 9. Spireme after synizesis.

Fig. 10. Diakinesis.

Figs. 11-14. First division spindle in basidium of fusion nucleus.

Fig. 15. Late telophase of the first division.

Figs. 16, 17, 18. Second division of the nuclei in basidium.

Figs. 19, 20. Late telophase of second division.

Fig. 21. Four nucleate basidium with centrosomes present.

Figs. 22, 23, 24. Change in nuclei and passage into the spores.

Fig. 25. Division in spore; two chromosomes going to each pole.

Fig. 26. Binucleate mature spore.

PLATE 50

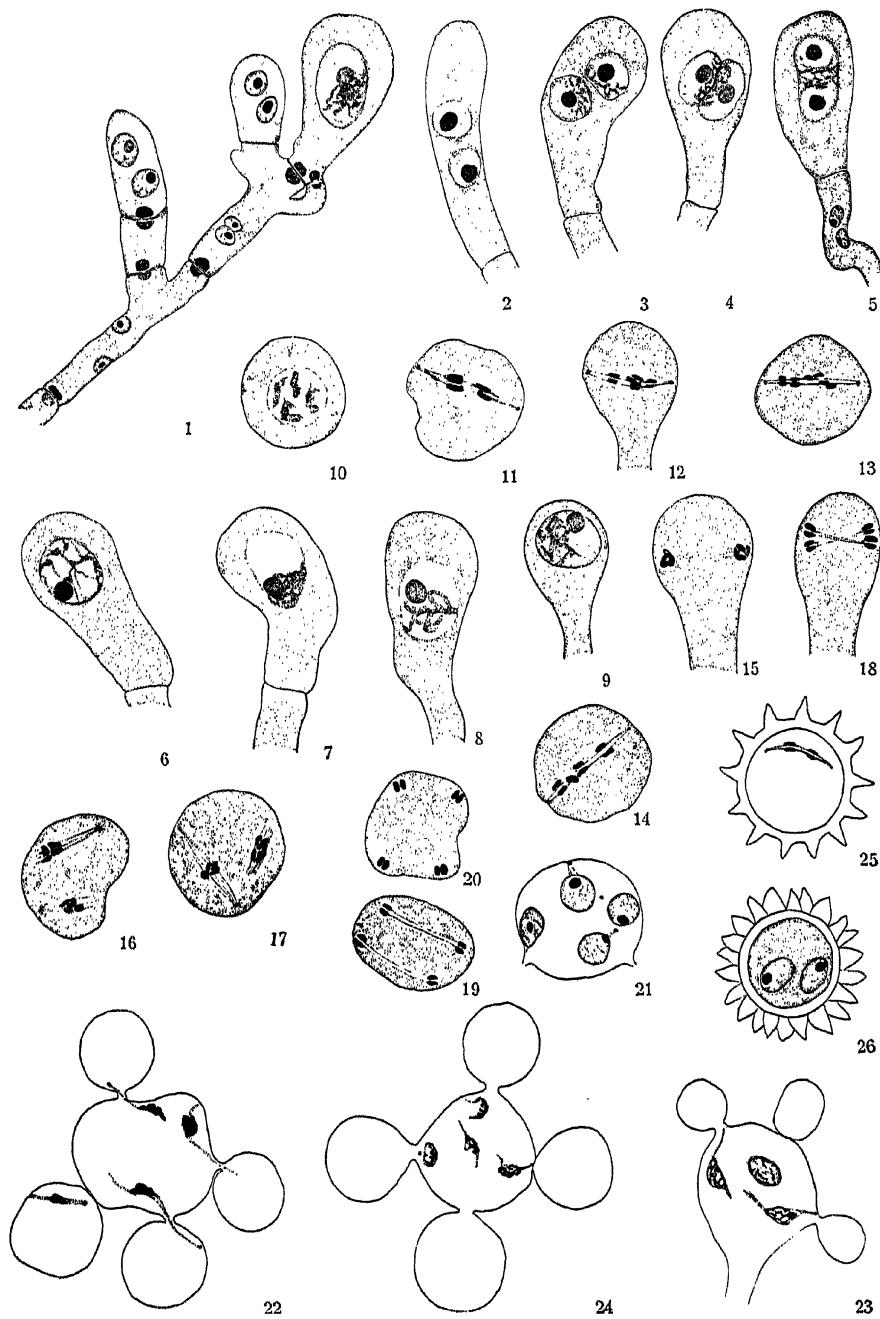


Fig. 27. Cavity primordia.  $\times 225$ .

Fig. 28. Early stage in cavity formation; tufts of basidial primordia branches radiating inward.  $\times 488$ .

Fig. 29. Cavity of older stage.  $\times 488$ .

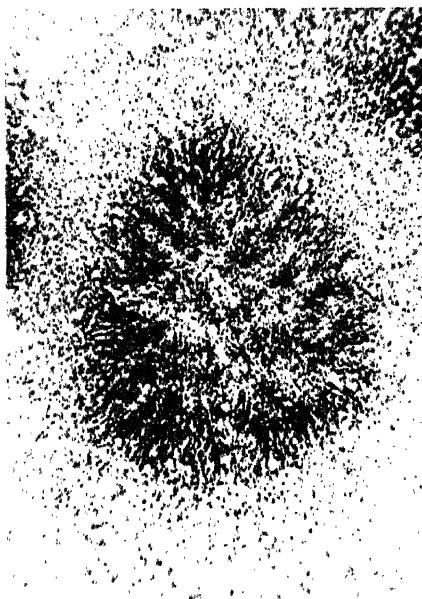
Fig. 30. Portion of trama plate and two cavities with basidia and spores.  $\times 488$ .

All drawings were made with an Abbé camera lucida at table level. A Spencer 1.5 mm. achromatic objective, N. A. 1.25, and a Leitz 15  $\times$  ocular were used, giving a magnification of about 3000 times. Plate reduced one-third.

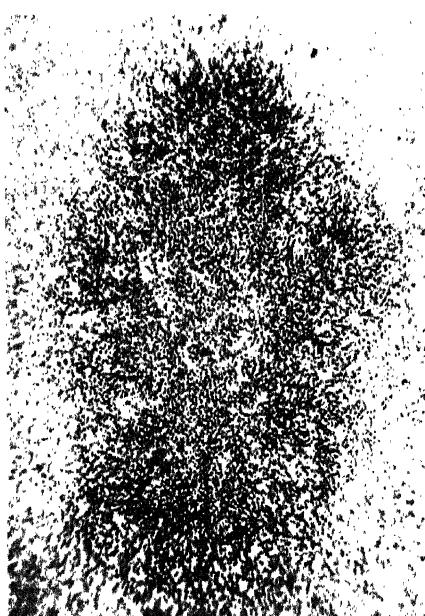
PLATE 51



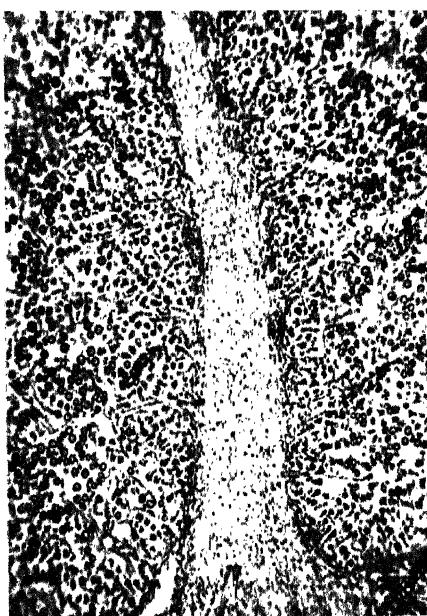
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## ACHLYA RECURVA CORNU FROM NORTH CAROLINA

By DENNIS H. LATHAM<sup>1</sup>

### PLATE 52

This rare fungus, first incompletely described by Cornu, has since been recorded by Hartog (6) and Miss Forbes (4, 5) from England, the former of whom gives no description, by Minden (8) from Germany who describes it rather fully but gives no illustrations, and by Lund from Denmark who had a very small amount of material and admittedly gives an incomplete diagnosis. If the plant illustrated by Miss Forbes is the same as ours, the egg structure as shown by her is incorrect. Since the fungus is incompletely known, it would seem of interest to give a more complete diagnosis with illustrations at the present time.

*Achlya recurva* Cornu. Ann. Sci. Nat. Bot., Ser. 5, 15: 22. 1872.

Growth fairly vigorous, but somewhat less vigorous than in *Achlya Orion* or *A. americana*, reaching a diameter of about 3 cm. Hyphae 20–90 $\mu$  thick near the base, the average being thinner than in most Achlyas. Sporangia only fairly abundant in young cultures, being very scarce in older ones, primary sporangia apical, renewed by cymose branching, typically broadest in the middle or toward the base, gradually tapering toward and rounding off at the tip. Spore development, discharge, and germination as typical for the genus; spores 11 $\mu$  to 16 $\mu$ , averaging 11 $\mu$  thick when encysted. Gemmae sparingly produced in old, healthy, aqueous cultures, abundant in contaminated water cultures and on potato agar containing 2 per cent sucrose. Oogonia usually lateral, on short, curved branches, which are from one to two times as long as the diameter of the oogonia; spherical but with numerous (up to 35), prominent cylindrical or slightly tapering protuberances 5–10 $\mu$  thick by 5–16 $\mu$  long, usually about 9 $\mu$  long, the ends truncate and with very thin walls. Oogonia 37 $\mu$  to 84 $\mu$  (protuberances not included), rarely as small as 25 $\mu$  thick, the average being about 42.8 $\mu$ . Oogonial wall unpitted except for the thin tips of the protuberances. A few atypical oogonia of irregular shape, sometimes intercalary and elongated, or twisted, or constricted in the middle, or with enormously elongated protuberances, are found in each culture. In such oogonia the eggs also are atypical in shape. Antheridial branches present on approximately seventy-five

<sup>1</sup> The writer wishes to express his appreciation to Dr. J. N. Couch of the Department of Botany in the University of North Carolina, Chapel Hill, N. C., under whose guidance the work was done and manuscript prepared.



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per cent of the oogonia; typically single, rarely two on an oogonium; usually androgynous, arising as a rule from the oogonial stalk or not rarely from the main hypha near the stalk origin, occasionally diclinous. The antheridium is short or long and usually applied laterally to the oogonium, becoming empty during the development of the eggs. Fertilization tubes present but difficult to follow because of the protuberances. Eggs 19-26 $\mu$ , averaging 23 $\mu$  thick, typically spherical but may become ovate to broadly elliptical due to pressure; 1 to 18, usually 4-8 in an oogonium, wall hyaline, 2 $\mu$  thick; usually not completely filling the oogonium; when mature, eccentric with a single, small, oil globule. Germinating upon maturity, or remaining quiescent for several months under certain conditions.

Deficiencies in previous descriptions make a close comparison of our plant with Cornu's species somewhat difficult. Cornu (3) mentions the oogonia covered with obtuse spines, the oogonial stalk being bent in an arch, and the number of eggs being usually from six to eight. He does not describe the antheridia. In Minden's more complete description the sporangia are described as being long-cylindric or slightly spindle-shaped, the secondary ones being few, the oogonial stalks recurved or bent like a bow and the walls furnished with many, blunt, hollow projections; the diameter of the oogonia from 50-90 $\mu$  with the spines 7-11 $\mu$  long; antheridial branches arising from the oogonial stalk, the main thread, or from another thread and also bent like a bow; the antheridia cylindrical or clavate and small; the eggs spherical, 1-25, mostly about 10 in an oogonium, 22-27 $\mu$  thick.

According to Lund (7) the oogonia are terminal on the main hyphae or on side branches which are bent; the oogonial wall is set with numerous blunt outgrowths, 6.6-13.2 $\mu$ , mostly about 9 $\mu$  in length, unpitted; the oogonia 49.5-72.6 $\mu$  thick (without outgrowths); oospores 23-30 $\mu$  thick, 3-9 in an oogonium. Lund's material was very scanty and he did not observe the sporangia nor did he see any antheridia on the few oogonia present in the culture.

The fungus described by Cornu, Minden, and Lund as *Achlya recurva* comes within the range of variation expected in this group and our plant agrees well with their descriptions, the only discrepancy being that Minden describes the oogonia as having 1-25 eggs, usually 10, while we have found 1-18, usually 4-8, a difference easily accounted for by variation or by the personal equation.

This fungus is closely related to *Thraustotheca primoachlya*. In fact it was at first thought to be that species, due to the close resemblance

of the oogonia and the fact that the eggs germinate so readily in both species. It is, however, distinguished from that species by the absence of the *Thraustotheca* type of sporangia which develop in cultures of *T. primoachlya* that are a few days old. The protuberances on the walls of the oogonia in *Achlya recurva* are longer than those on the oogonia of *T. primoachlya*, they are more numerous and symmetrically arranged, except on the few atypical oogonia which develop in most cultures. When the eggs in *T. primoachlya* germinate, they produce the *Thraustotheca* type of sporangia, while in *A. recurva* the germinating eggs produce the *Achlya* type of sporangia. Another striking difference between the two fungi is in the size of the oil globules in the ripe eggs, those in *A. recurva* being distinctly smaller than in *T. primoachlya*.

This fungus was collected from a moderately dry, red clay soil in a cotton field on the Central Experiment Station Farm at Raleigh, N. C., October 18, 1934. The original isolation was made by placing a small quantity of the soil in a Petri dish, covering it with water, and adding several pieces of boiled hemp seed. After about two days, when a fungus growth was visible, the pieces of hemp seed were washed with sterile water and transferred each to a separate Petri dish of sterile distilled water. When growth had continued for another twenty-four hours, a single hyphal thread was cut off and transferred to sterile water in a hollow ground slide. A very small piece of boiled hemp seed was added. The slide was then placed in a moist chamber for twenty-four hours. The hyphal tip continued to grow, becoming attached to the hemp seed. This culture was then transferred to sterile water in a Petri dish and was the source of all subsequent cultures.

Growth of the fungus on boiled hemp seed is moderately vigorous, the hyphae extending to a distance of 1.5 cm. from the seed in five to seven days. The mycelium forms a dense mat, i.e., the hyphal threads are very numerous. On yellow corn kernels the growth is not so vigorous as on hemp seed. The hyphae do not exceed 1.5 cm. in length in ten days and the mycelium does not form as dense a mat as on hemp seed. Growth of the fungus is scant on boiled acorns (*Quercus stellata*). The hyphae grow to a length of one to one and one-half centimeters in ten days. The number of hyphal threads which grow out from the acorn is very much smaller than the number produced on hemp. On all of the above named media young cultures of this fungus produce sporangia fairly abundantly. Sporangial development ceases almost entirely in cultures which are a week or more old. Oogonia are developed quite profusely in cultures on hemp and yellow corn, but not so abundantly

on acorns. Gemmae are produced in aqueous cultures a week or more old which have not had fresh water added to them during the time. The fungus grows well on two and one-half per cent potato agar containing two per cent sucrose, but produces neither sporangia nor oogonia. Gemmae are produced abundantly on potato agar.

There are very few records of egg germinations in the Saprolegniaceae. Trow (10) reported oospore germination for *Achlya americana* variety *cambrica* in 1898. Weston (11) reported the germination of eggs in *Thraustotheca clavata* in 1918. Coker (1) says in his discussion of *Achlya apiculata* var. *prolifica*, "This variety is the only member of the Saprolegniaceae in which we have been able to observe sprouting eggs." In *Thraustotheca primoachlya* the eggs germinate at room temperature after about ten days to two weeks (2). Usually when the eggs of that species germinate the germ tubes grow out through the projections on the oogonial wall for a short distance and form sporangia which later liberate a number of spores. Schlösser (9) working with three species and several varieties of *Saprolegnia* reported egg germination. He found that the normal rest period of the eggs varied from about three weeks in some species to three months or more in others. By subjecting the eggs to a temperature of  $-22^{\circ}$  to  $-24^{\circ}\text{C}$ . he found that many of them, in one case 50 per cent, had germinated after three days. In *Achlya recurva* the eggs mature in three days as indicated by their structure and are capable of germinating immediately. (These cultures were grown in an incubator at  $20^{\circ}$  to  $24^{\circ}\text{C}$ .) When the eggs germinate the germ tubes grow out through the protuberances. In a culture less than four days old a single oogonium containing four germinated eggs was observed. The single germ tube from each egg had grown out, each through a separate protuberance, to a distance of about fifty to seventy-five microns and a sporangium was formed at the tip of each hypha. The sporangia had each matured and discharged about five to eight spores which were encysted at the tips of the sporangia. Other cases of germination were seen in which the germ tubes had grown to a length of about two hundred microns before forming sporangia.

#### SUMMARY

*Achlya recurva* Cornu, a very rare and incompletely known species of water mold, isolated from a red clay soil on the Central Experiment Station Farm at Raleigh, N. C., October 18, 1934, is described. The fungus is characterized by the recurved oogonial stalks and by the numerous prominent cylindrical or slightly tapering protuberances which

adorn the oogonial walls, and also by the fact that the eggs are capable of germination a few days after maturing.

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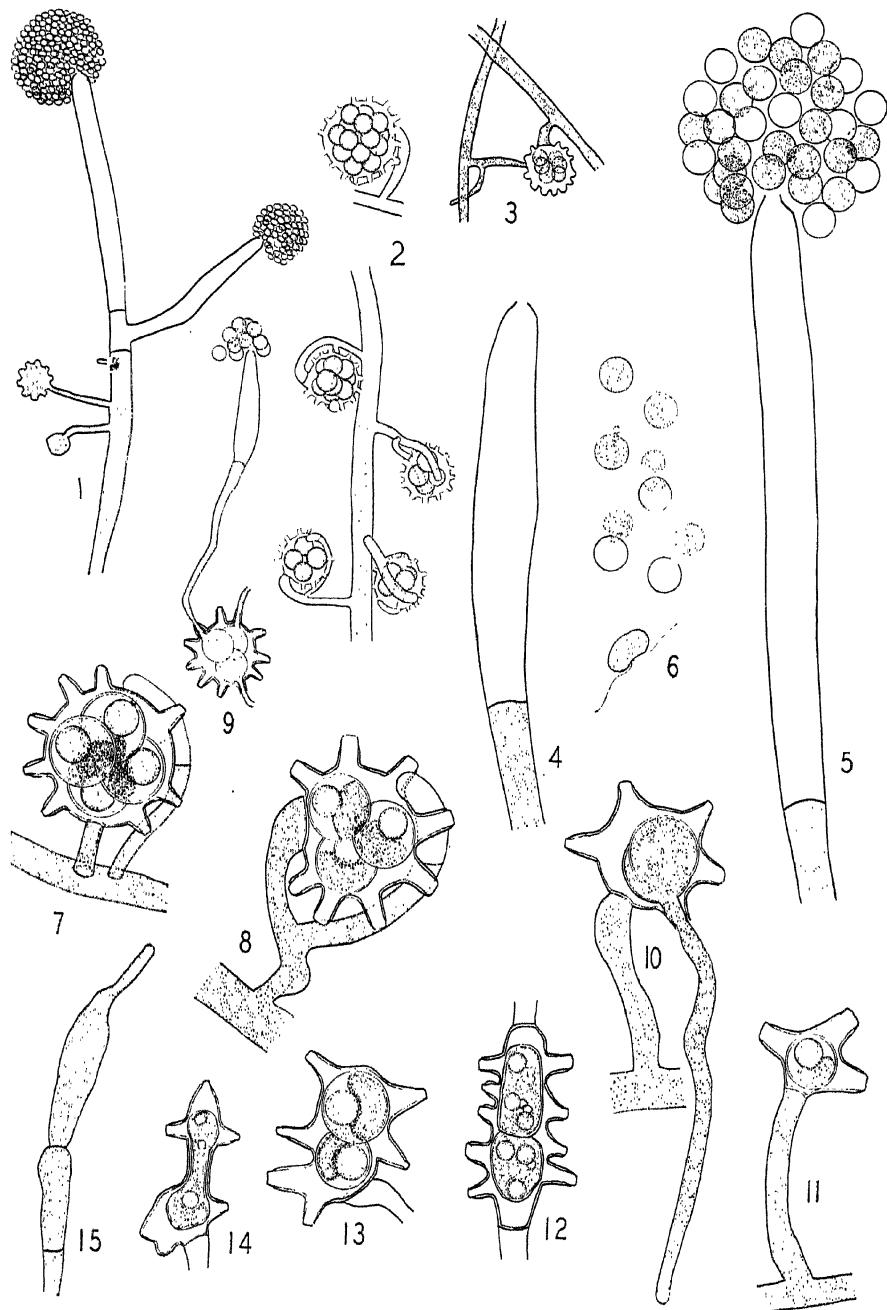
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## EXPLANATION OF PLATE 52

### *Achlya recurva*

- Fig. 1. Habit of fruiting.  $\times 93.$
- Fig. 2. Habit sketch showing oogonia and antheridia and one separate oogonium above.  $\times 110.$
- Fig. 3. Oogonium showing diclinous antheridial branch.  $\times 93.$
- Fig. 4. A typical empty sporangium.  $\times 440.$
- Fig. 5. Sporangium with spores clustered at tip.  $\times 440..$
- Fig. 6. Stages showing germination of cyst into a reniform spore.  $\times 440.$
- Figs. 7 and 8. Typical oogonia with androgynous antheridia and eccentric eggs.  $\times 880.$
- Fig. 9. Germination of eggs in an oogonium. Only one of the three sporangia which had formed are shown.  $\times 208.$
- Fig. 10. An oogonium with germinating eggs.  $\times 440.$
- Fig. 11. Oogonium with a single egg.  $\times 440.$
- Figs. 12-14. Three atypical oogonia.  $\times 440.$
- Fig. 15. Gemmae.  $\times 208.$

PLATE 52





## A REMARKABLE NEW RHODODENDRON

By W. C. COKER

PLATES 53 AND 54

### Rhododendron Ashleyi n. sp.

This description is drawn up from one plant in flower.

Plant about 3 feet high, very compact and fastigiate, foliage dense, bark resembling that of other rhododendrons; leaf blades lance-elliptic, somewhat twisted and bent at the tips, tapering at both ends, 6–7.5 cm. long by 1.4–2 cm. broad (some much smaller), about  $\frac{2}{3}$  mm. thick; margin even or slightly roughened, tip mucronate, midrib very prominent below, sunken above, other veins small and obscure. Petioles stout, about 1½–2 cm. long, petioles and lower side of leaves at first covered with pale brownish gray scurf which is partly worn off at the time of flowering and apparently entirely so by fall. Twigs of the year greenish, scurfy, stout. Flowers in a rather compact head, of about the same number as in *R. maximum*; corolla with a spread of about 3 cm., not glandular; petals all separate or (apparently about half) with the lowermost two fused about one-third the way up, the 4 lower alike, about 2 cm. long and about equal in width throughout, the upper one somewhat longer and with more undulate edges, more or less folded, strongly so and constricted below, this constriction containing the nectar. Color bright rose with a slight magenta tint, most intense at the tips and sides, fading to white below; upper lobe with light lemon yellow central area occupying the larger part of the broader distal half, this area very obscurely or less often plainly dotted with a few greenish splotches. Calyx lobes quite separate, oblong, blunt or slightly pointed, very variable in size without much regard to position, 3–5 mm. long, occasionally one up to 1.2 cm. their margins rosy; calyx and pedicel set with short rosy hairs; pedicels about 1.5–2 cm. long. Stamens normally 10, frequently 2 or 3 fused together to near the anthers, their lengths quite unequal, about 1–1.5 cm. long; filaments pure white, most of them at least with minute viscid glands; anthers very short, knob-like, dull yellow, not normal looking; pollen extremely scarce, probably none of it normal. Ovary about 3–4 mm. long, 2 mm. wide, longitudinally grooved, green, minutely glandular (in the particular ovary sectioned having six primary cells, imperfectly 12 due to the long recurved placentae). Style stout, bent slightly upward near its enlarged tip, about 1.2 cm. long, white; stigma flat, tuberculate, bright rose.

Bud scales boat-shaped and abruptly sharp-pointed to obovate with a long tapering point, 12–15 mm. long, greenish above, brown below, very minutely viscid glandular along central region of back.

Growing on a hill in Ashe County, N. C. (farm of H. M. Ashley), two miles from Lansing, surrounded by *Rhododendron maximum*, *Kalmia latifolia*, and various hardwoods in undisturbed forest (elevation about 2500 ft.). In bloom June 19, 1935, and still blooming and with some expanding buds on June 29; in faded bloom July 2, 1934. Raymond F. Ashley, collector.

This very remarkable plant is almost certainly an extreme mutant of *R. maximum*, as there is no other rhododendron in the vicinity and it resembles that species in the scurf instead of scales on the under side of the leaves and in the time of flowering. The flowers have the same color as pink forms of *maximum*. The plant is very probably entirely sterile, as indicated by the lack of pollen and of fruit. Its most remarkable characters are: entirely separate petals or at most the two lower slightly fused, entirely separate sepals, long, narrow, densely set leaves, and compact growth. The entire absence of disk-like scales on the under surface of the leaves shows that it is not connected with the *minus* group.

The writer visited Mr. Ashley and took a photograph of the blooming plant June 29, 1935. Mr. Raymond Ashley showed us three small ones left in the woods and said he was sure there were at least three more within the same small area of woods. Mr. Ashley had moved several others some time before in an effort to grow them but they had died. The large plant illustrated was moved into the yard of Mr. H. M. Ashley and is the only one large enough to flower. It is in healthy condition but these and all the others are of very slow growth. The smallest one seen had two stems and was only a few inches high. Either the younger plants are repeated mutations of apparently exactly the same kind or they are seedlings of the large plant. As this plant is apparently quite sterile, the first suggestion seems the more probable. In this case the appearance of repeated apparently identical mutations is a very remarkable occurrence in nature.

We take pleasure in naming this plant for Mr. Raymond F. Ashley, who first sent us a twig and leaves of it in May 1932; another in September, 1932; fading flowers in July 1934 and fresh flowers in full bloom in June 1935.

UNIVERSITY OF NORTH CAROLINA,  
CHAPEL HILL, N. C.

#### PLATE 53

RHODODENDRON ASHLEYI. PHOTOGRAPH OF PLANT AND DRAWINGS OF  
FLOWER, PETALS, AND BUD SCALES

PLATE 53

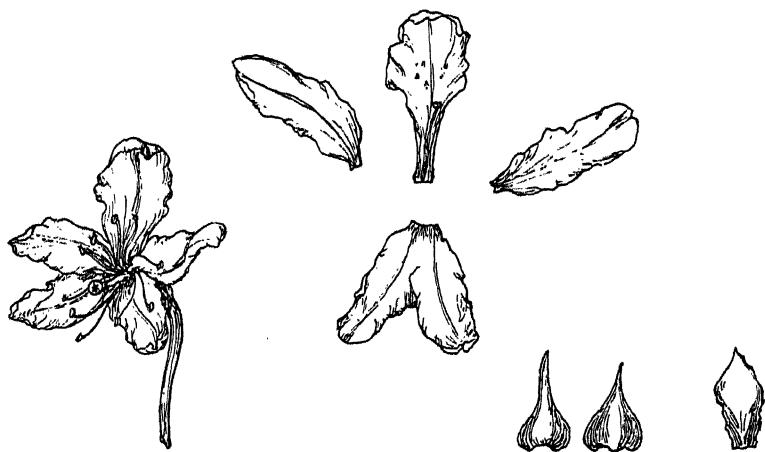


PLATE 54

RHODODENDRON ASHLEYI. ENLARGED ONE-FIFTH

PLATE 54





COLLIER COBB  
1862-1934

JOURNAL  
OF THE  
**Elisha Mitchell Scientific Society**

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Volume 51

December, 1935

No. 2

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PROCEEDINGS OF THE THIRTY-FOURTH ANNUAL  
MEETING OF THE NORTH CAROLINA  
ACADEMY OF SCIENCE

THE WOMAN'S COLLEGE OF THE UNIVERSITY OF NORTH CAROLINA,  
GREENSBORO, N. C., MAY 3 AND 4, 1935

The thirty-fourth annual meeting of the North Carolina Academy of Science was held at the Woman's College of the University of North Carolina, May 3 and 4, 1935. The meeting was called to order at 9:30 A.M. on May 3, by the president, Dr. H. R. Totten. The reading of papers was begun promptly and continued until 12:30 P.M. when the president announced the appointment of the following committees:

Auditing: A. D. Shaftesbury, G. R. MacCarthy, F. W. Sherwood.

Nominating: H. B. Arbuckle, Bert Cunningham, B. W. Wells.

Resolutions: W. L. Porter, M. L. Braun, J. B. Derieux.

The Academy then took a recess for luncheon.

The reading of papers was resumed at 2:15 P.M. and continued until 4:30 P.M. when the Academy held its annual business meeting.

The minutes of the previous meeting were approved as published in the *Journal of the Elisha Mitchell Scientific Society*.

Reports were then called for from the various committees.

The executive committee, consisting of H. R. Totten, the president of the Academy, P. M. Ginnings, vice-president, H. L. Blomquist, secretary and treasurer, Charles M. Heck, E. T. Browne, and W. E. Speas reported as follows:

"The executive committee met in Greensboro on May 2 and again on May 3 with all members present except Charles M. Heck who was unable to attend.

"The committee appointed E. T. Browne to act as temporary assistant to the secretary during the meeting.

"The committee acted favorably on the request by Dr. E. K. Plyler that his paper be transferred on the program from the general section to the physics section.

"Favorable action was also taken in response to the request by Dr. W. F. Prouty and Dr. G. R. MacCarthy that the places of their respective papers on the program be exchanged.

"The titles which arrived too late to appear on the printed program were accepted and added to the program, one before the general section and three before the physics section.

"The committee reported as elected to membership since the last annual meeting the following:

Bartlett, Grady, Dept. of Physics, State College, Raleigh, N. C.  
Beck, Clifford, Boyden High School, Salisbury, N. C.  
Billings, W. Dwight, Dept. of Botany, Duke U., Durham, N. C.  
Bloxam, Percy, Milford Mills, Salisbury, N. C.  
Boggess, W. R., Dept. of Botany, Duke U., Durham, N. C.  
Brimley, Ralph F. W., Reynolds High School, Winston-Salem, N. C.  
Carlsson, Victoria, Dept. of Hygiene, W.C. of U.N.C., Greensboro, N. C.  
Chamberlain, B. R., 1824 East 7th St., Charlotte, N. C.  
Coldwell, Inez, Dept. of Biology, W.C. of U.N.C., Greensboro, N. C.  
Correll, Don, Dept. of Botany, Duke U., Durham, N. C.  
Dearborn, D. C., Dept. of Math., Duke U., Durham, N. C.  
Deatrick, E. P., Erosion Exp. Sta., Statesville, N. C.  
Duncan, W. H., Dept. of Botany, Duke U., Durham, N. C.  
Edwards, Margaret, Dept. of Home Economics, W.C. of U.N.C.  
Eller, Frank, Dept. of Biology, Catawba College, Salisbury, N. C.  
Emory, S. T., Dept. of Geology, U.N.C., Chapel Hill, N. C.  
Evinger, E. L., Soil Erosion Nursery, Chapel Hill, N. C.  
Hard, W. L., Dept. of Zoology, Duke U., Durham, N. C.  
Harkema, Reinard, Dept. of Zoology, Duke U., Durham, N. C.  
Howe, M. Dorisse, Dept. of Biology, Queen's Chicora C., Charlotte, N. C.  
Huddle, J. W., Dept. of Geology, U.N.C., Chapel Hill, N. C.  
Johnson, W. R., Dept. of Geology, U.N.C., Chapel Hill, N. C.  
McCormick, J. C., Dept. of Geology, U.N.C., Chapel Hill, N. C.  
Merwin, Marion, Dept. of Biology, Catawba College, Salisbury, N. C.  
Middlekauff, Hugh, Dept. of Biology, Catawba College, Salisbury, N. C.  
Miller, James Kyle, 2100 Burlington Ave., St. Petersburg, Fla.  
Morgan, Karl Z., Dept. of Physics, Lenoir-Rhyne College, Hickory, N. C.  
Poole, Frazer, Dept. of Biology, Catawba College, Salisbury, N. C.  
Raynal, Chas. E., Statesville, N. C.  
Reed, John, Dept. of Botany, Duke U., Durham, N. C.  
Reed, Mildred Stites, Dept. of Botany, Duke U., Durham, N. C.  
Ruark, Arthur E., Dept. of Physics, U.N.C., Chapel Hill, N. C.

Ryburn, W. O., Jr., Dept. of Biology, Catawba College, Salisbury, N. C.  
Spangler, Helen, Dept. of Botany, Duke U., Durham, N. C.  
Summerell, Frances, Dept. of Biology, W.C. of U.N.C., Greensboro, N. C.  
Van Note, Wm. G., Chemical Engineering, State College, Raleigh, N. C.  
Webb, T. N., Dept. of Botany, Duke U., Durham, N. C.  
Williams, Myra A., Peace Junior College, Raleigh, N. C.

Other nominees were considered by the committee, and the secretary was authorized to consider these as elected upon payment of the initiation fee.

The following were reinstated to membership:

Bookhout, C. G., Elon College, N. C.  
Bullard, Lena, Greensboro High School, Greensboro, N. C.  
Campbell, Eva, Guilford College, N. C.  
Crittenden, Charles, W.C. of U.N.C., Greensboro, N. C.  
Dodson, C. F., Campbell College, Buies Creek, N. C.  
Douglas, J. M., Davidson College, Davidson, N. C.  
Edmister, F. H., Chapel Hill, N. C.  
Fritz, R. L., Lenoir-Rhyne College, Hickory, N. C.  
Harris, Mildred, W.C. of U.N.C., Greensboro, N. C.  
Klenner, Frederick R., Duke Hospital, Durham, N. C.  
Latham, Dennis, Dept. of Botany, State College, Raleigh, N. C.  
Ljung, Harvey A., Guilford College, N. C.  
Lutz, J. F., Dept. of Soils, State College, Raleigh, N. C.  
Lyon, Scott Cary, Davidson College, Davidson, N. C.  
Petty, Mary, W.C. of U.N.C., Greensboro, N. C.  
Purdom, Emil G., Guilford College, N. C.  
Saylor, John M., Duke U., Durham, N. C.  
Williams, Maude, W.C. of U.N.C., Greensboro, N. C.  
Yoder, M. C., Lenoir-Rhyne College, Hickory, N. C.

"The committee also reported the following losses during the year:

Lost by death:

Dr. Collier Cobb, Professor of Geology and former head of the department of Geology at U.N.C., Chapel Hill, N. C.

Lost by resignation because of removal from state:

McCay, M. S.  
Sims, I. H.

Lost by resignation:

Graham, Maria D.

Dropped from the roll because of non-payment of dues:  
Twenty-one former members.

The Treasurer's report was as follows:

*Financial Statement of the N.C.S.A. May 3, 1934 to May 1, 1935*

Receipts	Expenditures
Balance on hand May 4, 1934.. \$515.86	Stationery and Printing..... \$56.21
Dues for 1934..... 152.00	Same..... 72.28
Initiation fees for 1934..... 16.00	Addressographing..... 4.67
Dues for 1935..... 210.00	Postage..... 1.97
Initiation fees for 1935..... 46.00	Express on H. S. Essays and Stationery..... .93
Interest on savings..... 14.69	
Allotment from A.A.A.S..... 1.00	Long Distance Calls..... 1.70
N.C. Section Am. Chem. Soc. (Share toward programs).. 5.00	Books for H. S. Essay Prize (1934)..... 15.39
	Expenses for presenting prize.. 5.00
	Minute book for physics sec.... 1.20
	Clerical Assistance..... 53.20
	Dues refund to See..... 2.00
	Sec.-Treas. Commission..... 42.40
	Journal of E.M.S.S. (Partial payment, 1934)..... 150.00
	Tax on checks..... .38
	Charges on bank balance..... 1.50
	File and receipt books..... 1.70
	Total..... \$410.53
	To balance..... 550.02
	<b>\$960.55</b>

Comparison

	1934	1935
Savings Account.....	\$511.92	\$476.59
Checking Account.....	3.54	73.43
Cash on hand.....	.40	.00
	<b>\$515.86</b>	<b>\$550.02</b>
Outstanding obligation.....	150.00	135.00 (At present time)
	<b>\$365.86</b>	<b>\$415.02</b>
To balance (net loss).....	100.70 (gain)	49.16
	<b>\$466.56</b>	<b>\$365.86</b>

The above report was made as of May 1, 1935.

Submitted by H. L. Blomquist, Secretary-Treasurer.

Audited May 3, 1935 by

Archie D. Shaftesbury,  
Gerald R. MacCarthy,  
F. W. Sherwood.

"The committee accepted the invitation of the faculty and administration of Duke University to hold the thirty-fifth meeting in Durham.

"The executive committee made the following recommendations to the Academy:

1. That all bills presented in the Treasurer's Report be authorized and paid and that the Report be printed when audited.

2. That Bert Cunningham be appointed to select the books to be given to the winner of the High School Science Essay Prize, and that he be authorized to draw upon the Treasury for as much as \$25.00 for these books; and that the Secretary be authorized to appoint a representative of the Academy to award the prize and draw upon the Treasury for the payment of his expenses.

3. That the Academy elect to life membership Dr. E. W. Gudger of the American Museum of Natural History, New York City, and R. N. Wilson, Professor of Chemistry, Duke University.

Dr. Gudger joined the Academy in 1906, acted as its secretary and treasurer from 1908 to 1918, and as its president in 1919. Although he has been out of the state for many years, he has retained his active membership with a spirit of loyalty to the Academy and the state.

Professor R. N. Wilson joined the Academy in 1902, the year of the founding of the Academy, and acted as its vice-president in 1920.

4. That the library of the University of North Carolina be officially recognized as the depository of the Academy for exchanges and permanent records.

5. That the secretary be instructed to publish the revised Constitution and By-laws, list of past officers, and roll of present members with the 1935 Proceedings in the Journal of the Elisha Mitchell Scientific Society, and that 250 reprints be made; also that 50 reprints be made of the 1935 Proceedings for the purpose of exchange with other state academies, provided the total cost of reprints does not exceed \$40.00.

The auditing committee reported that they had examined the accounts of the treasurer for the period of May 4, 1934, to May 1, 1935, and found them correct.

The reports of the treasurer and auditing committee were accepted.

The committee on high school science, consisting of Bert Cunningham, chairman, H. B. Arbuckle, Lena Bullard, C. M. Heck, C. E. Preston, and R. N. Wilson, reported as follows:

"The usual activities have been carried on during the year. These consist of the assistance in the Divisional Meetings of the North Carolina Educational Association, and the conducting of the annual essay contest.

"Members of the Academy attended four of the six divisional meetings

and appeared on the programs, and also attended the state meeting where they virtually monopolised the program. While it is desirable that members of the Academy attend these meetings and occasionally appear on the programs, it appears to the committee that it would be better if more people engaged in high school work would appear on the program and discuss more fully their own problems. It is also desirable that a greater variety of college and university professors appear on these programs, and the Committee urges that invitations to appear on various programs be accepted, if received.

"The annual essay contest brought forth forty papers from twenty-seven competing schools. This number represents only a small part of the essays which were written for the contest since no school is permitted to submit more than three papers.

"The judges selected were: Chairman, E. H. Hall, Woman's College of the University of North Carolina, P. J. Kramer of Duke University, and J. N. Couch of the University of North Carolina. This committee selected Thelma Bardwell of Montreat College High School, as winner of the prize for her essay entitled 'Mental Hygiene.'

"The committee feels that a continuation of the contest is desirable and recommends that the subject for next year be restricted to the fields of Physics and Chemistry."

The report of the committee on high school science was accepted and its recommendations adopted.

The legislative committee, made up of Z. P. Metcalf, chairman, W. L. Poteat, and C. S. Brimley, did not have a report at this time.

The committee on the standardization of college science courses, consisting of Bert Cunningham, chairman, P. M. Ginnings, H. R. Totten, J. B. Bullitt, and K. H. Fussler, made a supplementary report as follows:

"Section B of this report was laid on the table at the last meeting of the Academy in order that members of the Academy might have more time for deliberate consideration of the provision of an Appraisal Committee, and that the Committee might have more time to get the reaction of administrative officers who would of necessity have to coöperate if the plan is to be a success.

"The Committee has attempted to get the viewpoint of administrative officers by submitting Section B to them and asking for frank comments concerning the plan. A sufficiently large proportion of them have replied, and the replies have come from various types of institutions so that a summary may be made of their views. In a word, the great

majority believe that this would be a good project if it is properly protected and if the smaller institutions are protected.

"With the additional information at hand, your committee is ready to recommend the adoption of Section B of its earlier report."

This report was accepted and the committee discharged.

The following memorial report honoring the late Dr. Collier Cobb, was presented by the chairman of a special committee:

DR. COLLIER COBB

The death of Professor Collier Cobb on November 28th, 1934, at Chapel Hill has taken from the North Carolina Academy of Science one of its most loyal supporters.

Professor Cobb was born at Mt. Auburn Plantation, Wayne County, North Carolina, on March 21, 1862. His journalistic talents developed early. In childhood he wrote, printed, and distributed a small newspaper; and as a Harvard student he instituted what is believed to be the first syndicated news service.

Following two years at Wake Forest and one at the University of North Carolina, Professor Cobb taught for five years in the secondary schools of the state before going to Harvard where he received the A. B. and M.A. degrees. During his last two years at Harvard he was instructor in the Massachusetts Institute of Technology.

In 1892 Professor Cobb came to the University of North Carolina as Assistant Professor. The following year he was made Professor and first head of the Department of Geology.

Professor Cobb was closely associated with the activities of the Academy of Science from the time of its first annual meeting in 1902. He responded to the address of welcome at this first meeting, was the sixth president of the Academy, and during his 32-year membership seldom failed to present one or more papers at each meeting.

Professor Cobb possessed an extremely active mind and an untiring energy. His interest in world affairs and in travel made him nearly as well known abroad as in the United States. His interest in humanity was genuine and far reaching. This interest, coupled with a keen knowledge of people and customs, together with his deep sense of humor and his gift of interesting conversation, led to many contacts and friendships with all classes of people in his world travels. His striking personality, keen intellect, and remarkable memory, expressed in a wealth of rare anecdotes, made him the central figure in any group. Always an interesting lecturer and public speaker, he was much in

demand for this purpose. His teaching and personality so impressed his students that many of them went on to successful careers in geology, and in later years the sons and daughters of former students sought out Professor Cobb's classes as a high spot of interest in their college experiences.

Although Professor Cobb's publications cover a wide field of thought, his major interests were those of human geography and shoreline processes and development, as shown by the following titles: *Where the Wind Does the Work*, *Lands and Dunes of Gascony*, *Loess Deposits of China*, *Early English Survivals on Hatteras Island*. His Pocket Dictionary of Common Rocks and Rock Minerals was much used throughout the country, and his map of North Carolina ran through six editions.

Professor Cobb lived to realize one of his greatest ambitions in the firm establishment of an active department of geology at the University of North Carolina before he resigned as head of the department in 1932 and began the preparation of a book of reminiscences. It is most regrettable that he did not live to finish this work which would have held so much of value and interest for many people both here and abroad.

In the best sense Professor Cobb was a Christian. He was a loyal member of the Baptist Church, supporting its activities with his counsel and his purse. He gave liberally to the cause of Christian missions, regardless of denominational affiliation, and could be counted on to support any deserving cause. Long a deacon of his church and a Sunday School worker, he was one of the most influential Baptist laymen in the state, always exerting his influence for liberalism in religion.

Professor Cobb was always prompt to recognize and perform his duty. He was a loyal citizen, a good neighbor, interested in the activities of the University, the town and the state, a man of high ideals, optimistic, and eternally young.

A gentleman of the old school, yet always forward looking, Professor Cobb will be remembered as one of the most vivid personalities of our group. His death removes one of the best known and best beloved citizens of the state. It is given unto few to have touched and influenced as many lives as did Professor Cobb in his long and useful career.

Wm. F. PROUTY,  
W. L. POTEAT,  
J. L. STUCKEY,  
*Committee.*

The report was accepted by a standing vote and the secretary was instructed to place the report in the minutes and to send a copy to the family.

The general resolutions committee reported as follows:

"The Academy hereby expresses its appreciation of the hospitality of the Woman's College of the University of North Carolina.

"In particular we desire to mention the manner in which the committee on arrangements has anticipated every need and comfort of the Academy.

"We desire also to recognize the cordiality and coöperation of the Chamber of Commerce of the city of Greensboro. To all of these agencies we are largely indebted for such a pleasant and profitable meeting."

M. L. BRAUN,  
J. B. DERIEUX,  
W. L. PORTER,  
*Committee.*

The above resolutions were adopted.

A recommendation was made and passed that the committee on public school curriculum be revised.

C. F. Korstian, the representative of the Academy to the A.A.A.S., reported as follows:

Two matters should be brought before the Academy:

1. The A.A.A.S. is attempting to stimulate the organization of junior academies in the various states through the state academies. In this connection it might be well to point out the possible desirability of stimulating the organization of local science clubs in a number of our larger high schools and in some of the larger or more aggressive communities. This seems preferable to sponsoring the so-called junior academies.

2. Concerning the organization of local branches of the A.A.A.S. it is suggested that our Academy pass a resolution that whenever the organization of local branches of the A.A.A.S. is contemplated, we would urge upon the officials of the A.A.A.S. that the local academy be fully consulted before such steps are taken.

The report was accepted.

A motion was made and carried that the Academy go on record as not favoring junior academies, but as being willing to encourage and offer its services to help high school science clubs.

A second motion was made, that the secretary communicate with the Permanent Secretary of the A.A.A.S. and request that the state academies be consulted before establishing local branches of the A.A.A.S. This motion was passed.

A third motion was made stating that the Academy is not in favor of the establishment of a Southeastern Branch of the A.A.A.S.

After some discussion, this motion was also passed.

Following a discussion concerning the destruction of non-timber trees and shrubs in the state by the activities of the CCC organizations, a committee, consisting of Chas. E. Raynal, B. W. Wells, and J. P. Givler, was appointed to draw up a resolution, which follows:

Whereas it has been brought to the attention of the North Carolina Academy of Science that in certain places an apparently ruthless and unnecessary destruction of thousands of trees and shrubs both of aesthetic and commercial value, has resulted from the activities of the CCC organizations, the Academy presents the following resolution for consideration:

Be it resolved that the North Carolina Academy of Science is greatly disturbed over the excessive destruction in certain places of the valuable trees and shrubs in our National and State Forests.

As citizens of the United States and interested in the conservation of our timber trees and native shrubs, we call attention to what we consider a short-sighted and dangerous policy in the use of the CCC men in our forest areas. We petition:

1. That a more exact determination be made of the meaning of the terms "timber" vs. "weed" trees. We call attention to the fact that holly and dogwood, for example, have a commercial value, greatly in excess of the ordinary timber trees and should be protected from excessive or wanton destruction.

2. That when non-timber trees and shrubs do not interfere with more important growth, they be preserved.

3. That the policy of setting aside special areas where these plants will be left entirely undisturbed, be carried out to a larger degree, resulting in a reasonable increase in such areas in every State and National forest.

It is suggested that this resolution be placed in the hands of all high administrative officers concerned, including the President, the Director of the Forest Service, the Director of the CCC camps, the Governor of North Carolina, the Director of the Erosion Control Service, and the North Carolina State Forester.

The nominating committee submitted the following nominations:

*President*—W. L. Porter, Davidson College.

*Vice-president*—F. W. Sherwood, State College.

*New member of the Executive Committee* (for three years)—H. R. Totten, The University of North Carolina.

The nominations were accepted and the secretary was instructed to cast the ballot of the Academy for the nominees.

The president then announced the appointment of the following committees:

Legislative Committee: Z. P. Metcalf, chairman, W. L. Poteat, Wm. F. Prouty.

Committee on High School Science: Bert Cunningham, chairman, H. B. Arbuckle, C. E. Preston, Mrs. B. W. Wells, Lena Bullard, Nancy Eliason.

Committee on Public School Curriculum: C. E. Preston, chairman, Mrs. B. W. Wells, Lena Bullard.

Committee on Zoological Nomenclature: Z. P. Metcalf, chairman, C. E. Stiles, R. E. Coker.

Conservation Committee: Chas. E. Raynal, chairman, B. W. Wells, J. P. Givler, T. G. Harbison, C. F. Korstian, W. C. Coker, C. S. Holmes.

Elective Appraisal Committee: General Section, E. H. Hall, R. E. Coker, Mary Conrad Cleaver. Physics Section, C. W. Edwards, Karl Fussler, E. G. Purdom. Chemistry Section, R. N. Wilson, J. T. Dobbins, P. M. Ginnings.

The business meeting then adjourned.

At 6:45 P.M. the members of the Academy were entertained at a complimentary dinner given by the Woman's College in South Dining Hall.

The Academy reconvened at 8:30 P.M. in the auditorium of the Student Building with P. M. Ginnings, the vice-president presiding. Dean Geneva Drinkwater welcomed the Academy to the Woman's College and to Greensboro. President H. R. Totten delivered his presidential address entitled "The Caprifoliaceae or Honeysuckle Family in the Southeastern States." The address was well illustrated by herbarium specimens.

At 9:30 P.M. the Academy members and visitors met for an enjoyable social hour in Society Hall.

On Saturday morning the Academy met in sections. President Totten presided over the general section; E. R. C. Miles over the

mathematics section with W. N. Mebane, Jr. as secretary; Calvin N. Warfield over the physics section with J. S. Meares as secretary; and J. M. Saylor over the chemistry section with W. C. Vosburgh as secretary.

The following officers were elected by the respective sections:

*Mathematics Section*—Chairman, W. N. Mebane, Jr., Davidson College; Secretary, V. A. Hoyle, The University of North Carolina.

*Physics Section*—Chairman, C. C. Hatley, Duke University; Secretary, J. S. Meares, North Carolina State College.

*North Carolina Section of the American Chemical Society*—Chairman, R. W. Bost, The University of North Carolina; Vice-chairman, A. M. White, The University of North Carolina; Secretary-treasurer, W. C. Vosburgh, Duke University; Councilor, L. A. Bigelow, Duke University; Executive committee, the officers, J. S. Black, Wake Forest College, H. D. Crockford, The University of North Carolina, F. W. Sherwood, North Carolina State College.

The following papers were presented. Those marked with \* appear in full in this issue. Those marked x are abstracted with the Proceedings. Those marked † were read by title.

#### GENERAL SECTION

x*Further Observations on the Effect of Increased Atmospheric Pressure on the Incubating Hen Egg* (Lantern). BERT CUNNINGHAM, Duke.  
x*Economic Uses for Cellulose Materials of the Coastal Plain*. E. E. RANDOLPH, State.

x*Resistance of the Air to Golf Balls at Different Velocities*. J. B. DERIEUX, State.

x*Effect of Nitrogen Fertilizers on Strawberry Production* (Lantern). R. A. LINEBERRY, U. S. D. A., and H. B. MANN, State.

*Menhaden Fish Oil as a Source of Vitamin D for Growing Chicks* (Lantern). J. O. HALVERSON, R. S. DEARSTYNE, F. H. SMITH and F. W. SHERWOOD, State.

*The Structure of Plant Cell Walls* (Lantern). DONALD B. ANDERSON, State.

x*Further Observations Concerning the Origin of the "Carolina Bays"* (Opaque Lantern). WM. F. PROUTY, U. N. C.

x*Meteors and the Carolina Bays* (Opaque Lantern). GERALD MACCARTHY, U. N. C.

*Observations on Downy Mildew of Tobacco*. FREDERICK A. WOLF, Duke.

x*After-Effects in the Stretching of Rubber* (Lantern). MILTON L. BRAUN, Catawba.

*Fertility of Diploid Males and Triploid Females in the Wasp Habrobracon (Lantern).* C. H. BOSTIAN, State.

x*The Effect of Length of Day and Soil Temperature upon Nodulation of Soybeans (Lantern).* C. B. CLEVENGER, State.

*A Survey of the Liverworts of North Carolina.* H. L. BLOMQUIST, Duke.

x*An Adventure in Natural Science Education.* B. W. WELLS, State.

\**A Study of the Cave Spider, Nesticus pallidus, to Determine Whether It Breeds Seasonally or otherwise.* J. D. IVES, Carson and Newman College.

*The Effect of Various Cations on Certain Physico-Chemical Properties of Soil Colloids (Lantern).* J. F. LUTZ, State.

*A Study of North Carolina Species of Cyperus and their Distribution.* MILDRED STITES REED, Duke.

*Two New Sac Fungi.* W. C. COKER, U. N. C.

*Question Concerning Conservation of the Non-Timber Trees and Shrubs in the National Forests of North Carolina.* T. G. Harbison, U. N. C.

*Oil Films on Water: their Peculiar Motions and Physical Properties.* CHAS. M. HECK, State.

x*Some Aspects of the Chemical Engineering Laboratory.* C. S. GROVE, State.

x*Behavior of Chrome-Nickel Alloys in Phosphoric Acid Solutions (Opaque Lantern).* W. C. WALLIN and C. S. GROVE, State.

*Origin, Development and Function of the Oenocytes of the Honeybee, Apis mellifica Linn.* A. D. SHAFTESBURY, W. C. of U. N. C.

x*Contact as a Stimulus to Localized Growth (Lantern).* W. C. GEORGE, U. N. C.

*The Effect upon a Cecil Clay Type of Soil from a Continuous Application of Mineral Plant Food Elements (Charts).* G. M. GARREN and E. E. RANDOLPH, State.

x*Work of the Soil Erosion Experiment Station (Lantern).* E. P. DEATRICK, Statesville.

*Time Elements in Transmission of Radio (Lantern).* G. W. BARTLETT and C. M. HECK, State.

*Recent Advances in the Knowledge of the Atomic Nucleus.* C. W. EDWARDS, Duke.

*Parasites of North Carolina Rodents.* REINARD HARKEMA, Duke.

x*Systematic Zoology (Lantern).* Z. P. METCALF, State.

†*New Parasites from North Carolina Frogs (Lantern).* B. B. BRANDT, Duke.

†*A New Achlya from the Soil (Lantern).* DENNIS H. LATHAM, State and U. N. C.

†x*The Silurian of Eastern Tennessee* (Opaque Lantern). WM. F. PROUTY,  
U. N. C.

x*Regeneration of Functional Testes in Birds* (Lantern). BERT CUNNINGHAM,  
Duke.

x*An Attempt to Locate the Boundaries of the Durham Triassic Basin with  
a Magnetometer*. W. R. JOHNSON, JR., and H. W. STRALEY,  
U. N. C.

#### MATHEMATICS SECTION

x*Solutions of a Simple Type of Stieltjes-Integro-Differential Equation*.  
F. G. DRESSEL, Duke.

x*Complete Sets of Inequalities on Arithmetical Invariants of Pfaffian  
Systems*. D. C. DEARBORN, Duke.

x*Associated Algebraic and Partial Differential Equations*. JOSEPH A.  
GREENWOOD, Duke.

*On Monge's Differential Equation*. J. W. LASLEY, JR., U. N. C.

x*On the Matric Equations  $P(X) = A$  and  $P(A, X) = 0$* . EDWARD T.  
BROWNE, U. N. C.

#### PHYSICS SECTION

x*The Isothermal Elongation of a Stretched Rubber Band* (Lantern).  
MILTON L. BRAUN, Catawba.

\**Change of Resiliency with Velocity of Impact* (Opaque Projection).  
J. B. DERIEUX, State.

*Some Comments on Recent Studies of Cosmic Ray Showers*. W. M. NIELSEN,  
Duke.

*Ionization of Neon and Argon by Singly Charged Magnesium Ions*  
(Lantern). J. C. MOUZON and N. H. SMITH, Duke.

*A Discussion of the Classical Aspect of the Ionization of Gases by Slow  
Positive Ions*. J. C. MOUZON, Duke.

*The Variation with Temperature and Magnetization of the Thermoelectric  
Behavior of Ferromagnetic Substances*. F. W. CONSTANT and F. E.  
LOWANCE, Duke.

*A Preliminary Report of the Absorption Spectra of  $CO_2$  and  $HCl$* . A. P.  
CLEAVES, Duke.

x*The Infrared Absorption Spectra of Acetic Acid and Acetic Anhydride*.  
E. K. PLYLER and E. S. BARR, U. N. C.

x*On the Half Lives of Potassium, Rubidium, Neodymium and Samarium*.  
ARTHUR E. RUARK and KARL H. FUSSLER, U. N. C.

*Some Theorems on Statistical Fluctuations in Radioactive Phenomena*.  
ARTHUR E. RUARK, U. N. C.

*Evidence for Shell Structure in the Atomic Nucleus.* KARL H. FUSSLER,  
U. N. C.

#### EXHIBITS

*Granites of Rowan County.* EMMETT E. CRUSE, Jr., Catawba.

*Soil Erosion.* E. P. DEATRICK, Statesville.

NORTH CAROLINA SECTION OF THE AMERICAN CHEMICAL SOCIETY

*The Quantitative Determination of Cobalt in the Presence of Iron.* J. T. DOBBINS, U. N. C.

*The Relative Ease of Removal of Hydrogen Bromide from Certain Brom-amides by means of Alkali.* C. R. HAUSER and W. B. RENFROW, Duke.

x*Gassing-Voltage-Gravity-Temperature Relationships in Lead-Acid Storage Cells.* H. D. CROCKFORD and W. R. SINK, U. N. C.

x*The Isolation of a New Cyclic Amino Acid.* E. W. MCCHESEY, U. N. C.

*Some Factors Affecting the Solubility of Slightly Soluble Organic Liquids in Water.* J. M. SAYLOR, J. C. RINTELEN and P. M. GROSS, Duke.

*Business Meeting*

*The Determination of Sodium and Potassium in Lake Deposits.* C. S. BLACK and C. M. PRESLAR, Wake Forest.

*Oxidation-Reduction Equilibria in Soils.* L. G. WILLIS, State.

*The Preparation of Pure Fluorine and its Continuous Reaction with Hexachlorobenzene.* LUCIUS A. BIGELOW and WILLIAM T. MILLER, JR., Duke.

*Ternary Systems; Water, Allyl Alcohol and Salts at 25°.* P. M. GINNINGS and MARY DEES, Greensboro College.

x*A Color Test for the Identification of Mono-, Di- and Trinitro Compounds.* R. W. BOST and FRANK NICHOLSON, U. N. C.

*Activity Coefficients for 0.1 to 4 Molal Aqueous Hydrochloric Acid Solutions.* W. F. WYATT, JR., Wake Forest.

The following abstracts have been received:

*Further Observations on the Effects of Increased Atmospheric Pressure on the Incubating Hen Egg.* BERT CUNNINGHAM.

Further experiments indicate that there is an acceleration in the growth rate of chick embryos under pressure. Desiccation of such embryos reveals an increase in weight of organic materials indicating that the growth is real and not due to hydration.

More elaborate studies of the effects of pressure on post-hatching growth, which was earlier suggested, show that while there is neither earlier hatching nor greater hatching weights, the pressure chicks grow more rapidly after hatching.

Although one might expect some marked effect on the sex ratios on the "metabolic theory" of sex, no such effect is apparent in the data, which it must be admitted is neither adequate nor satisfactory for a final decision.

*Economic Uses for Cellulose Materials of the Coastal Plain.* E. E. RANDOLPH.

The census report indicates that over seven million cords of wood are consumed annually in the United States in pulp making and it is estimated that more than one hundred million cords have been used in making paper and pulp and that of this enormous amount of wood approximately 75 per cent has been Spruce and Balsam. The supply of these types of trees is therefore so greatly diminished that other sources of suitable cellulose raw materials must be discovered to supply the demand. State College Chemical Engineering Department is making a careful study of the timber growth of the Coastal Plain to find the economic values of the different types of trees native to this area.

Many thousands of acres of land are marshy and cannot be successfully drained for agricultural purposes. The land, however, is extremely fertile, the climate is mild; hence a large variety of trees grow naturally on this swampy land so that the period necessary for a tree to reach maturity is much shorter in this area than it is in northern climates.

It has been found that some of these timbers make excellent fiber which when prepared under proper conditions is suitable for practically all purposes. Other types of trees have limited range as suitable pulp material. Good paper, rayon, cellophane, plastics and varnish have been made from the Cypress and Pine. These studies include also other cellulose raw materials such as peanut hulls, grass, and other cellulose producing raw materials.

The necessity of this study is apparent from the following considerations:

1. The enormous amount of paper and pulp required to supply the needs of the country;
2. The rapidly diminishing supply of trees formerly used and the consequent increase in cost of the present available supply;
3. Indications that suitable pulp can be economically prepared from other kinds of trees and other kinds of other raw materials;

4. The vast areas in this state suitable for rapid timber growth and entirely unsuitable for any other use;
5. The possibility of stimulating industrial activity in an area in which not a great variety of industries exists;
6. The nature of cellulose itself;
7. The nature of other constituents of wood available for pulp.

In these studies it is assumed that cellulose is identical regardless of its source; that the cellulose molecule may not be as complex as is sometimes believed, that the cellulose molecule consists of four  $C_6H_{10}O_5$  units symmetrically arranged with reference to each other or of some multiple of these four symmetrical units; that each unit contains three alcohol groups, two secondary and one primary; that cellulose is a relatively inactive body; and that because of its trihydric nature its reactions in the production of conversion products necessarily proceeds in steps, so that if conditions are not rigidly controlled intermediate products are also acted on, resulting in a final product far from uniform.

Various kinds of woods contain different kinds of associated constituents such as lignin, tannin, resins, and gums which are partially removed in the pulping process. The different kinds of timber require different chemical treatment to remove these constituents. Oxidizing agents and alkalies attack some of the cellulose converting it into oxycellulose and even to glucose as an end product, whereas acid treatment unless rigidly controlled may convert some of the cellulose into dextrin, into polyose groups, and finally may proceed to glucose.

It is apparent that if proper conditions can be observed the undesirable associated constituents may be removed to a reasonable degree without seriously attacking the cellulose itself. The extent of this purification process must be determined from the nature of the tree. A number of these trees give favorable results.

*Resistance of the Air to Golf Balls.* J. B. DERIEUX.

The following data on the resistance of the air to golf balls, were obtained by suspending the balls in a wind tunnel. The manner of suspension was that of a simple pendulum, with the fixed end of the fine thread attached at the origin of a large circular degree scale on cardboard, the cardboard being vertical and parallel with the wind. The angular deflection of the pendular arrangement, when the wind was blowing, was read at the point where the thread crossed the degree scale, with which it was in close contact at all times. The resistance was computed from the right-angled force triangle of the three forces under which the ball was in equilibrium. The equation for it is  $R =$

$W \times \tan \theta$ , where  $W$  is the weight of the ball, and  $\theta$  is the angular deflection. The velocity corresponding was read from tunnel gauge, after calibration by anemometer.

The golf balls used were of the present standard dimensions, 1.62 ounces in weight, and 1.68 inches in diameter, but had been played with some, so that they had an average weight of only 1.60 ounces.

#### DATA

TUNNEL GAUGE <i>in.</i>	DEFLECTION TANGENT	VELOCITY OF AIR <i>ft./sec.</i>	WEIGHT OF BALL <i>lbs.</i>	RESISTANCE OF AIR <i>lbs.</i>
1.37	$4.54 \times 10^{-2}$	24.0	0.100	$4.54 \times 10^{-3}$
1.75	5.94 "	27.5	0.100	5.94 "
2.00	6.47 "	29.8	0.100	6.47 "
2.38	7.87 "	33.0	0.100	7.87 "
2.69	8.93 "	35.3	0.100	8.93 "
2.94	9.45 "	37.0	0.100	9.45 "
3.31	10.50 "	39.4	0.100	10.50 "
3.62	11.04 "	41.2	0.100	11.04 "
3.88	11.92 "	42.5	0.100	11.92 "
4.28	12.63 "	44.3	0.100	12.63 "
4.50	13.52 "	45.6	0.100	13.52 "

The next part of the problem was to determine the relation of resistance to velocity. Plotting a graph with velocity as abscissa and resistance as ordinate, a smooth curve was obtained, which substantiated the data, but it curved upward, thus showing that the resistance increased faster than the first power of the velocity. A graph with the second power of the velocity curved downward, indicating that the resistance did not increase so rapidly as that. Therefore, it was evident that the increase was between the first and the second power of the velocity. Assuming an exponential form, the equation  $R = CV^x$  was set up, where  $R$  is the resistance,  $C$  a constant,  $V$  the velocity, and  $x$  the power of the velocity. Two simultaneous equations were derived from this by taking two values of  $R$  and the corresponding values of  $V$  from the data, and solving for  $x$  and for  $C$ . It gave 1.63 for  $x$ , and  $2.62 \times 10^{-6}$  for  $C$ , where  $R$  is in pounds, and  $V$  in feet per second. Thus the equation of resistance is  $R = 2.62 \times 10^{-6}V^{1.63}$ . Plotting a graph between velocity to the 1.63 power and resistance, a beautiful straight line was obtained, thus verifying the exponential assumption, and its solution.

The maximum velocity obtainable in the wind tunnel was not very large, but having determined the law of resistance and velocity, as expressed by the preceding equation, it was then possible to compute the

values of the resistance for much higher velocities. It is interesting to note that in a good golf drive, the velocity of the ball as it leaves the club is about 240 feet per second. The resistance of the air to its flight at that stage is 0.2 pound, or twice the weight of the ball, as computed from the formula. Another interesting point is, that for a resistance of the air just equal to the weight of the ball, its velocity would have to be 158 feet per second. Applied to a golf ball dropped from an airplane, this means that while its velocity would increase 32.2 feet per second per second when it was first dropped, this would be gradually decreased by the increase in the air resistance as the ball increased in velocity, and would be 0.0 when the ball attained a velocity of 158 feet per second, the resistance being equal to the weight of the ball, after which it would fall with a constant velocity of 158 feet per second. This would be after a fall of about 2000 feet, as computed from another line of reasoning (see article entitled "Change of Resiliency with Velocity of Impact," in this issue).

This piece of work came as adjunct to another which I was doing, which was on the change of the resiliency of the balls with velocity of impact by the method of fall-and-rebound. In the greater heights of fall and rebound, which I was using, it was necessary that I know the resistance of the air, so as to correct for it in computing the velocity of fall and of rebound.

*Effect of Nitrogen Fertilizers on Strawberry Production.* R. A. LINE-BERRY, and H. B. MANN.

Results of experiments comparing sources of nitrogen in complete fertilizer mixtures, and time of application of nitrogenous fertilizers upon yields, carliness, shipping qualities, and viability of strawberries, are herein reported. On Norfolk sandy loam, fertilizers containing varying proportions of sodium nitrate and cottonseed meal gave the largest yields of strawberries when 80 per cent of the nitrogen was derived from sodium nitrate and 20 per cent from cottonseed meal, but on Coxsackie sandy loam largest yields were secured each year when the nitrogen was derived equally from sodium nitrate and cottonseed meal. The ammonium sulphate-cottonseed meal mixtures gave largest yields each year on both soil types when the nitrogen was derived equally from the two materials.

Strawberries of better firmness and shipping quality were produced when the fertilizer mixture contained both organic and inorganic nitrogen than when containing inorganic nitrogen alone.

The replacement of slowly available organic nitrogen sources by quickly soluble inorganic nitrogen salts changed the chemical nature of the soil, resulting in low viability of strawberry plants during the summer. This condition was generally associated with high soil acidity and total soluble salts.

Spring applications of either sodium nitrate or ammonium sulphate, in addition to complete fertilizer applied in midsummer and early fall, were injurious if their effect upon earliness and shipping qualities of strawberries is considered. Application of 16 pounds of nitrogen per acre from either sodium nitrate or ammonium sulphate increased the yield slightly over 20 per cent, while larger applications were less effective and were attended by delayed ripening and consequent lower prices for the strawberries. The greatest loss, however, resulted from the poor shipping qualities of the strawberries fertilized with a spring application of nitrogen. Applications of 16 pounds of nitrogen per acre from either sodium nitrate or ammonium sulphate greatly increased the percentage of soft berries after being subjected to shipping conditions, while applications of 32 pounds rendered them almost unfit for shipping purposes, especially for long distances.

*Further Observations Concerning the Origin of Carolina Bays.* W. F. PROUTY.

About three years ago members of the Department of Geology of the University of North Carolina<sup>1</sup> began the investigation of the nature of elliptical bays and lake basins in the Coastal Plain area of the Carolinas.

As a result of that study a paper was recently published<sup>2</sup> in the *Journal of Geology* favoring the meteoric theory of the origin of these elliptical bays and lake basins. In this article it was shown that there is a magnetic high to be found in association with most of the elliptical depressions and that in most cases the center of this high is a little to the east of south of the southeast end of the elliptical depression and removed from the southeast end a distance about equal to the short axis of the ellipse.

Since the publication of the above article, further field investigation<sup>3</sup> has yielded additional evidence supporting the meteoric theory of the origin of these elliptical depressions. In the previous article it was pro-

<sup>1</sup> W. F. Prouty, G. R. MacCarthy, and J. A. Alexander.

<sup>2</sup> Carolina Bays and Elliptical Lake Basins, *Jour. Geol.* 43, No. 2: pp. 200-207, 1935.

<sup>3</sup> W. F. Prouty, G. R. MacCarthy, and H. W. Straley.

posed to make a test case of Dial Bay, and its two associated smaller bays, located near Turbeville, South Carolina. From the theory proposed, there should be found a high magnetic area a little to the east of south from the southeast end of Dial Bay and at a distance about equal to the short axis of the Dial Bay ellipse. The single high magnetic area which had previously been located was assigned by the theory to the eastern of the three bays, and it was held that the high from Dial Bay should be located to the east of south from the southeast end of that bay. Field investigation shows a high area, made up of three minor highs, which fulfills this prediction. It would appear that these minor highs show the presence of three buried portions of the Dial Bay meteor. A small high area to the west of the three high magnetic areas associated with Dial Bay is, in turn, apparently connected with the small bay on the southwest flank of Dial Bay.

Additional magnetometer investigation was made in the area to the northwest and north of White Lake, Bladen County, N. C. The investigation proved this unusually high magnetic area to be eccentrically elliptical, with the magnetic lines of force more closely spaced toward the north. The size of this high and its location conform in general to the theory of a buried magnetic body associated with the origin of the huge bay which is located a little to the west of north of the magnetic high and at a distance equal to the short axis of the bay from the southeast end of the bay.

#### *Meteors and the Carolina Bays.* GERALD R. MACCARTHY.

Over 90 per cent of the bays so far investigated show a magnetic high in the proper location to be caused by a meteorite such as would produce the bay with which the high is associated.

Theoretical considerations, substantiated by experiments using high-power bullets, indicate that the bays themselves are the result of the explosive air-blast accompanying the meteorites, and are not simply "punch holes."

From this it follows that the formations lying beneath the bays must be undisturbed except for the much smaller "bullet holes" produced by the meteorites themselves, and since the bays have been filled with sand and swamp-muck the discovery of such holes could be made only by accident.

A comparison of the "bay country" with the area in Siberia affected by the great meteorite fall of 1908 shows that the effects produced in the two regions differ in magnitude rather than in kind.

*After-Effects in the Stretching of Rubber.* MILTON L. BRAUN.

Twelve similar rubber bands were suspended from the ceiling of a glass door apparatus cabinet last August. Each of three of the bands was slowly given a gravity load of 350 g, another three 550 g, others 750 and 1000 g. Measurements of the lengths of the bands were made at the moment of release of the load, at numerous intervals during the first day, and then daily to date (240 days) or to the breaking of the band. Although the bands were subject to room temperature fluctuations only those observation taken at 27°C were used in determining the relationship between elongation and time. For the first twenty to forty days all bands seemed to lengthen at a positive fractional power rate. The rates according to decreasing magnitude being those for the 550, 750, 1000, and 350 g loads, respectively. Curves for bands having the three highest loads were found to approximate a linear relationship between length and time from about the fortieth day to the breaking point of the band. However, in the case of the highest load there is a very slight upward trend after about 180 days. Curves for the bands with the lowest load were found to pass through a very gradual inflection in the neighborhood of forty days into an ascending power form which continued until the bands finally broke. The bands did not break with a gradual tear but with a sudden snap.

*The Effect of Length of Day and Soil Temperature upon Nodulation of Soybeans.* C. B. CLEVENGER.

In greenhouse work involving the question of nodulation on soybeans, it was found that the same results in nodulation were not obtained at different seasons of the year, although the soils in which the soybean plants were grown had received similar fertilizer treatments. This suggested that some uncontrolled factor as length of day or temperature was operating.

An experiment was set up to test out these two factors. Soybeans were grown in soil in gallon pots placed in two water tanks. One tank had a temperature range of 20-25°C, and the other was kept at 35°C using a thermostat. Plants at both temperatures were then subjected to both short and long day conditions. The experiment was made during October. For the short day plants the period of light was approximately eight hours, and for the long day plants the period of illumination was extended by the use of artificial light to 10 P.M. All pots were inoculated with soybean organisms.

The results of the experiment are as follows:

- (1) The size of the plants varied with the day length for each of the fertilizer treatments, but was not affected by soil temperature.
- (2) The root systems of the plants varied inversely with the soil temperature and directly with length of day.
- (3) The number of nodules on the roots of the plants of each pot were about the same irrespective of the temperatures and length of day.
- (4) The size and dry weights of the nodules were greater on the roots of the plants grown at the lower temperature whether under long or short day.

The soil used, a Coxville sandy loam, was selected at random and for no specific soil property. It is probable, therefore, that the temperature effect upon the size of the nodules is a specific one. This same effect was observed in work at Wisconsin. Recent work by Hopkins of Chicago shows length of day to be a factor in nodule development, which is not confirmed by this experiment.

*An Adventure in Natural Science Education.* B. W. WELLS.

Report on a 3 months summer course given to freshman and sophomores in 1933 and 1934 at the Columbia University mountain school, known as New College Community, under the direction of Dr. Thomas Alexander of Teachers College. The course emphasized plant science but was unique in that the course throughout was given an ecological complexion. The first three weeks were given to field studies constituting an introduction to the problems of adaptation as these appear in the connection with community distribution. From the very beginning the elementary student was made as equally conscious of habitat as he was of organism. The brief and necessarily superficial ecological introduction was followed by the usual survey of plant structure and functions, but in addition habitat factor measurements were made in the field to supplement the laboratory studies with the microscope and physiological demonstrations. Accompanying the study of the leaf, for instance, photometer measurements were made of a large number of habitats and a number of atmometer readings made at contrasting stations. This carry-over into field situations of functional concepts (something seldom done in the regular college courses in biology) proved most valuable. One full day each week throughout the summer was devoted to field observations during which time all of the major successions were worked out. The course closed with the introduction of a few major animal relations and finally a brief summary of the rôle of the plant communities (including the crops) as the plant life of the region was

related to human life and industries (Canton paper mill, sawmills, etc.) of the area.

The interest aroused through the ecological emphasis in this course in elementary biology, was sufficient to warrant the suggestion that our local institutions of higher learning look forward to the development of similar summer courses in the mountain area. Science requirements in the fields of Botany, Zoology, and Geology could be worked out by the elementary student under the most favorable conditions and time be gained during the regular school year for other studies.

*Some Aspects of the Chemical Engineering Laboratory.* C. S. GROVE, JR.

The development of a good Chemical Engineering laboratory is governed by the three factors of type of experiments available, time available, and equipment available.

The preliminary work is done during the sophomore and junior years. During these years, the student studies the basic equipment used in the process industries and the special types of industrial control equipment. He also learns to use the hand and machine tools of the forge, foundry, wood, and machine shop.

Special emphasis is laid on his Chemical Engineering laboratory during his senior year. He must study the various unit processes of flow of fluids; flow of heat; crushing and grinding; mechanical separation; filtration; humidity and drying; evaporation; distillation, absorption; and extraction.

Complete technical reports are required on investigations of each. Calculations of efficiency of operation are also required. In his later work, he must design and construct some type of machinery for use under specified conditions.

During the whole course, emphasis is laid on the importance of the student's preparation for his life's work, so that, all his tests must be definitely correlated with actual plant practice and operation.

*The Behavior of Chrome-Nickel Alloys in Phosphoric Acid Solutions.*

W. C. WALLIN and C. S. GROVE, JR.

For several years, a study of corrosion has been carried on in the Chemical Engineering laboratories at N. C. State College. A definite paucity of information on the corrosion of steels in phosphoric acid solutions was shown by a study of the literature.

Fifteen samples of chrome-nickel steels were subjected to corrosion in phosphoric acid solutions of 0.1 N, 0.5 N, 1 N, 2 N, and 5 N concentra-

tions. These tests were made under controlled conditions of temperature.

Measurements of the rate of corrosion in inches penetration per month were made in hundred hour periods. From these measurements it is concluded that:

(1) Each metal when exposed to the corroding solution reached a maximum rate of corrosion between the one hundred and two hundred hour period; (2) From the two hundred hour period on, the rate gradually diminished for each metal until some rate was reached at which corrosion proceeded fairly constantly or the rate was asymptotic to some value; (3) The amount of chromium or of nickel originally present gave no reliable indication of the behavior of the alloy when exposed; (4) The resistance of an alloy in one concentration was not a reliable index to its behavior in another concentration of phosphoric acid; and, (5) The following samples showed the best corrosion resistant properties in all of the concentrations of phosphoric acid No. D-Misco-N-10 per cent Cr and 20 per cent Ni, No. J-Calite E-18 per cent Cr and 8 per cent Ni; and No. M-Misco-C 29 per cent Cr and 9 per cent Ni.

*Contact as a Stimulus to Localized Growth.* W. C. GEORGE.

Localized growth, which plays such an important part in the development of organisms, is in some cases a result of pressure stimulation. Proof that localized pressure on the cambium causes localized growth in plants is to be found in various types of phenomena familiar to every woodsman. Some examples are: the ridges developed where separate tree trunks or approximately parallel limbs of the same tree have been in contact for some years, the growth of wood over stones or over planks placed as seats between trees, and the enlargements where tree trunks or limbs have been bound by vines. A case of the latter type that I have observed permitted of quantitative study. It was a sweet gum sapling closely bound by a honey-suckle vine throughout a zone 78 cm. in length. Determinations, stated in percentages, showed: the average bulk in the region of stimulation is 44 per cent greater than in the trunk below and 60 per cent greater than in the trunk just above; the average weight is increased 55 per cent over that of the trunk below and 118 per cent over that of the trunk above.

In animals too there is evidence that pressure is an effective stimulus to localized growth. For example, Fischer and Schmieden transplanted a section of a vein into the course of an artery. It took on the character of an artery, i.e., its connective tissue content increased and its muscular

walls were more than doubled in thickness. The greater pressure in the artery was doubtless the determining factor for increased thickness. According to the third of the Laws of Thoma: The growth in thickness of a vessel wall depends on the tension of the wall, which in turn is dependent upon the blood pressure and the diameter of the vessel.

The phenomenon of growth in response to pressure stimulation has various implications. Appearances suggest that pressure may be an important stimulus in certain regions of the vertebrate embryo. I will cite (1) the active proliferation in the nephrogenic cord where the metanephric evagination of the mesonephric duct presses into it, (2) the proliferation resulting in the formation of the neural crests in the region of fusion of the neural folds, (3) the origin of the mesoderm from the line of fusion of the lips of the blastopore.

In the field of abnormal development there are certain teratomas and parasitic fetuses which tend to occur along lines where fusions took place in embryonic development. A common explanation of the cause of these abnormalities is that one of two incompletely separated or too closely placed uniovular twins has been fused with an more or less completely incorporated into the body of the host twin. This interpretation is almost certainly true for some cases and may be for all. But in view of their tendency to occur along lines of fusions and in view of the proliferative stimulus exerted by contact, we cannot ignore the possibility that some of these teratological structures may be the result of a sort of abortive reproduction through a process of budding such as is common in many lower forms of animals.

*The Effect upon a Cecil Clay Type of Soil from a Continuous Application of Mineral Plant Food Elements.* G. M. GARREN and E. E. RANDOLPH.

The effect upon crop yields of a continuous annual application of mineral plant food elements is yet one of the unsolved problems in all its details of agricultural research. An aid in the solution of this problem would be a study of the effect upon the soil itself of such a system of fertilization. On the Piedmont Branch Station of the North Carolina Experiment Station, in Iredell county, a continuous series of fertilizer tests have been systematically conducted for 31 seasons, 1903-1933 inclusive, on a Cecil Clay type of soil. The  $\frac{1}{20}$  acre plats were cultivated in a four year rotation of cotton, corn, wheat, and red clover. Each season there was applied to each crop the mineral plant food elements, alone or in combination, that would meet the plant's requirements for those elements deficient in that particular soil type. The

elements usually deficient in this type of soil are nitrogen, phosphorus, and potassium. The amounts applied each season and the total crop yields for the 31 seasons have been recorded. Among the series of plats at regular intervals are located check plats that received no fertilizer treatment. To determine the effect of this system upon the soil itself two plats as nearly adjacent as possible were selected for soil analyses. Upon one a complete fertilizer, containing all 3 elements, had been applied; the other was a check plat. A quantitative chemical analysis of the soil from these two plats were made for the 3 elements.

The effect of such a system upon crop yields will be illustrated by the yields of grain from the corn crop in the rotation. During these 31 seasons 8 crops of corn were grown in the rotation with a total yield of 731.36 pounds of grain from the fertilized plat and 199.64 pounds from the unfertilized plat. These records show a total increase of 531.72 pounds in favor of the fertilized plat—a 266.33 per centum increase due to the fertilization. Yet only a total of 4.5 pounds of nitrogen, 10.5 pounds of phosphorus pentoxide, and 2.25 pounds of potash were applied to this  $\frac{1}{10}$  acre plat. These very small applications caused this very large increase in total yields. Similar results can be illustrated with any of the other crops grown in the rotation.

Three samples of soil at measured distances and at the three strata depths of 8, 6, and 6 inches were collected and mixed in a composite sample for each plat and then chemically analyzed for total nitrogen, phosphorus, and potassium. The results in percentages are tabulated below.

EFFECT UPON CECIL CLAY TYPE OF SOIL OF LONG CONTINUOUS FERTILIZATION  
(31 SEASONS)

STRATA	DEPTH	MINERAL PLANT FOOD ELEMENTS					
		Fertilized plat			Unfertilized plat		
		N <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	N <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
	inches	per cent	per cent	per cent	per cent	per cent	per cent
Top soil.....	8	.0786	.113	.786	.0756	.075	.54
Subsoil.....	6	.0653	.075	.7825	.0498	.05625	.60
Subsubsoil.....	6	.0453	.077	.79	.0473	.06375	.66

Be it noted that the percentages of nitrogen are practically the same for both plats. There is some increase in total phosphorus in the fertilized plat and considerable increase in total potash. The amounts of these elements naturally belonging to this type of soil were increased by

the fertilizer applications. On the check plat they were drawn upon by the crops grown thereon. Then the crops grown on the fertilized plat after exhausting the amounts artificially applied did not draw upon the natural amounts to the extent they did on the check plat. Possibly all the artificial applications were not taken up by the growing plants. Hence the difference in the percentages in the two plats. Note also that the percentage of the natural phosphorus in this type of soil is very low; the potash very high.

*The Work of the Soil Erosion Experiment Station at Statesville, North Carolina.* E. P. DEATRICK.

An individual frame film of the physical plant and its operation were shown, accompanied with a lecture giving the salient points. The 1931-1934 data from the control plots were graphically presented and samples of relative amounts of the soil and water run-off were exhibited.

*Systematic Zoology.* Z. P. METCALF.

The importance of systematic zoology was stressed and the idea was advanced that systematic zoology was not a static science and that we would never have an absolutely stable nomenclature. The following divisions of systematic zoology were proposed:—Systematics, Nomenclature, Taxonomy, and Phylogeny. In Systematics the importance of carefully prepared descriptions and illustrations was stressed. The importance of bibliographies and catalogues was discussed and descriptions and illustrations of the different types of keys were shown. Nomenclature was defined as that branch of systematic zoology which deals with names and not with the animals themselves. Selection of names should be based on laws even where the laws seem to run counter to common sense. Taxonomy was defined as that branch of systematic zoology which defines the fundamental units of the animal kingdom. Definitions were proposed for genera, species and varieties. Phylogeny was defined as that branch of systematic zoology which describes the evolutionary descent of organisms and their arrangement into some sort of system to show their interrelationships. The difficulty of reconstructing phylogenetic trees was pointed out. The past history of systematic zoology was briefly described, together with the growing complexity and difficulties encountered in dealing with the large number of genera and species. The important landmarks in the development of systematic zoology are:—1) the expression of the species concept by John Ray before 1700; 2) the development of binomial nomenclature by

Linneaus in the 10th Edition, *Systemae Naturaे* in 1758; and 3) the phylogenetic concept by Lamarck in the earlier years of the 19th century. Three important historical periods may also be recognized:—1) a period of expansion from 1758 to about 1825; 2) a period of exploration from about 1800 to 1850; and 3) a period of specialization from about 1850 to the present time. In discussing the future of systematic zoology the point was stressed that it would be continually changing because there would be a constant interplay between systematic zoology and morphology, embryology, genetics, nomenclature, phylogeny, systematics, zoogeography, and taxonomy.

*Silurian of Eastern Tennessee.* W. F. PROUTY.

The Silurian of eastern Tennessee is best developed in the northern portion of the state and in the central portion of the "Valley and Ridge Province." In the Bays Mountain Area, chiefly in Greene and Hawkins Counties, there is a considerable development of white and red sandstone much resembling the Medina and so mapped in the Greeneville and Morristown Folios of the United States Geological Survey. These sandstones are overlain by red and gray shales and sandstones somewhat resembling the Rockwood and so mapped in the two above mentioned folios. Abundant fossils in the New Hope Area and in Blair Gap section prove these shales and sandstones to be of Cincinnati Age. There is apparently no Silurian present in the Bays Mountain Area.

Going westward from the Bays Mountain Area ("Athens Trough") the Silurian comes in rapidly. In Stone Mountain and in Clinch Mountain in the eastern part of the "Cumberland Basin," ten and twelve miles respectively westward from Bays Mountain, both the Juniata (red Medina), and Tuscarora (white Medina) are represented by about 400' thickness of strata. In Stone Mountain the Tuscarora is overlain by the Chattanooga Black Shale, but in Clinch Mountain, about two miles to the west, 12' of Oriskany sandstone intervene between the Tuscarora and the black shale. In most exposures this Oriskany carries an abundant and characteristic fauna, but does not in the Bean Gap section which accounts for its not being recognized in the cross-section prepared for the transcontinental field trip.<sup>1</sup> The upper portion of the Tuscarora in the Bean Gap section is somewhat shaly and has been called Clinton by some geologists.

<sup>1</sup> Guide Book 3, Excursion A-3, XVI International Geological Congress, 1933.

Going westward from Clinch Mountain another twelve miles we find in Powell Mountain that the Medinas, both red and white (Juniata and Tuscarora) have been greatly reduced in thickness, and the latter in part replaced by the Brassfield. On the other hand the Clinton has come in and attained a thickness of more than 400' and the overlying "Hancock" or "Sneedville" limestone, of Cayugan age, has come in and thickened to about 125'. Fifteen miles farther northwest at Cumberland Gap the Cayugan rocks have disappeared and the place of the Tuscarora between the Clinton and the Juniata has been taken by a few feet of very fossiliferous red limestone of Brassfield Age.

Going southwestwardly in Tennessee from the cross-section just described from near the Virginia border, we find a rapid thinning and disappearance of the Hancock and a general thinning of the Clinton. The Brassfield, represented by a few feet of limestone at base of the Clinton in Cumberland Gap section, thickens and replaces the Clinton and is the chief representative of the Rockwood in many of the central and southern exposures in the Eastern Tennessee Silurian belt. In this direction also the Juniata becomes very shaly and limy and loses all its Medina characteristics. In the Sequatchie Valley the thin-bedded red or red-and-buff calcareous shales of the Sequatchie formation underlying the Brassfield have their typical development. In southeastern Tennessee a cross-section of the folded Appalachians shows a less radical change in the Silurian sediments than the one described from the northern state border.

Throughout the southern border area the Chattanooga black shale immediately overlies the Rockwood, chiefly Brassfield. Eastward from Chattanooga the Silurian thickens considerably. In Oak Mountain, near Ooltewah, the Silurian reaches a thickness of nearly 1000', Clinton at top, but chiefly Brassfield, while in the Sequatchie Valley it is less than two hundred feet thick with no Clinton represented.

*Regeneration of Functional Testes in the Birds.* BERT CUNNINGHAM.

Since the days of Berthold there have been repeated reports of the regeneration of the gonadal materials in the bird. Some of these may not legitimately be considered as regeneration processes, such as, for example, the appearance of a testis upon the right side of an animal which has lost through disease or operation the functional ovary of the left side. Here there is apparently the development of primitive germinal tissue which has been inhibited by the ovary, when it was properly functioning; the strange fact being that at times this tissue even though

it be in a female body, develops into a male gonad. There are records which show that this gonad functions both as an endocrine organ and as an actual producer of functional sperm. Such animals have been mated and have proved to be fertile.

As suggested, for our purposes, the above phenomena are not considered as regeneration, but the term is restricted to those cases where gonadectomy has been performed and there appears at a later time new gonadal tissue either at the original site or elsewhere within the body.

As one should naturally expect, the fact that gonad regeneration occurs, was first discovered when the so-called secondary sex characters were observed to reappear in the castrated bird. This phenomenon is endocrinial, being associated with the production of the male hormone, presumably by the interstitial tissue, which incidently is not actively involved in spermatogenesis. The evidence first to appear in the secondary sex characters of the bird is the reddening and growth of the comb. In birds of the regenerate type exploratory examination reveals masses of tissue which when histologically examined prove to be testicular and in some cases this is showing active spermatogenesis. In some of these birds the regenerated tissue comes to approximate in size and histological character the normal testis, but more often the masses are comparatively small, irregular in shape and frequently found quite distant from the original testes sites. Such bodies when smeared often show motile sperm.

The occurrence of regeneration is most often explained on the basis of an imperfect castration, the idea being that either a rudiment of a gonad was left *in situ* or else the rupture of the gonad gave an inadvertent transplant to the viscera of the operated animal. The large number of regenerates occurring in our pens, some appearing a year or more after the original operation, suggested that possibly careless technique was not altogether to blame for the appearance of regenerates in our stock. With this in mind the testes of our later capons were preserved so that in case regeneration occurred we could check our first operations.

One bird of this lot began showing regeneration about a year after castration. There was a rapid growth of comb until it approximated the cock size. Superficial examination of the testes which had been removed led us to believe that the first operation had been successful and complete. Before performing any exploratory operations, this bird through the aid of a local poultry-man, Mr. L. G. Cheek, was mated with four different lots of virgin pullets. Eggs taken from these before

mating were properly tested for fertility by incubation, and in all cases they proved infertile. The mating was then made and after five days the eggs which were collected and incubated showed fertility, the best test coming in one of the spring matings when in one lot of eggs the fertility compared favorably with the general run of eggs secured from the same stock (not same individuals) with normal cocks.

This observation means that not only has this bird been able to regenerate new tissue but it has also been able to connect this tissue with the ducts in such manner as to provide for the discharge of sperm in a normal manner. This functional regeneration has been observed by Hutt, but only when the epididymis has been uninjured and a mass of tissue equivalent to one sixth of the original testis left, presumably in contact with the epididymis. In the case reported here, examination under the binocular microscope fails to reveal any part of the testes missing, certainly there could not be so much as one twenty-fifth of the original testis left *in situ*.

The birds produced by mating this regenerate male with virgin pullets compare favorably with our normal chicks from this same stock in growth rate and appearance.

In another setting of 24 eggs about a week later there were 5 infertile eggs, 5 developed for about 7 days, two were unable to get out of the shell and 12 hatched. Of these latter 11 were healthy and normal at 10 days. In general the data for this clutch are similar to that presented above.

After these mating experiments exploratory operations were performed. The site on the right side was clean, the epididymis being observed. On the left side there was an unusually large testis, highly vascularised. It measured approximately 1.8 cm. through the short axis and 4 cm. through the long axis. A stout band of connective tissue encircled the structure midway on the long axis. The kidney overlapped the testis. Hemorrhages resulting from an effort to remove the gonad produced the death of the bird.

From these data it is evident that either this resultant testis originated from a far smaller mass of original tissue than ever observed previously or else it has originated *de novo* from some primitive tissue in the region.

*An Attempt to Locate the Boundaries of the Durham Triassic Basin with a Magnetometer.* W. R. JOHNSON, JR., and H. W. STRALEY, III.

This survey was undertaken to establish the practicability of determining, entirely on the basis of variations in the earth's magnetic field, the boundaries of a sedimentary series surrounded by igneous and

metamorphic rocks. It was hoped that the difference in magnetic permeability between the various kinds of rocks was such that boundary determinations could be made with sufficient accuracy for most geological purposes. The Durham Triassic basin appeared to be admirably adapted to such a study.

The geology of the area has been described by Dr. W. F. Prouty (Amer. Jour. Sci. 21: 473-490. 1931) and others. The sedimentary rocks are arkosic sandstones, clays, conglomerates, fanglomerates, etc., cut by mafic dikes and sills, the latter particularly concentrated in the northwestern half of the basin. The sediments were derived from the igneous and metamorphic rocks directly to the northwest and southeast. The depth to the crystalline basement is more than 500 meters at Durham.

As a result of this survey the writers have concluded in the main that:

1. Were the area under sufficient cover to obliterate the surface geology, it would be impossible to determine the exact limits of the basin, although its existence could be hypothesized.
2. Only where faulting has occurred can the boundary be determined with certainty.

*Solutions of a Simple Type of Stieltjes-Integro-Differential Equation.*

F. G. DRESSEL.

This paper presents the general solution of the equation,

$$u''(x) + l(x)u'(x) + m(x)u(x) + n(x) \int_a^b [P(t)u(t) + q(t)u'(t)] dB(t) = 0,$$

and also discusses the existence of solutions satisfying arbitrary initial conditions on the solution and its first derivative.

*Complete Systems of Inequalities on Arithmetic Invariants of a Pfaffian System.* D. C. DEARBORN.

Associated with a pfaffian system are certain arithmetic invariants. Four of these are the class  $p$ , the species  $\sigma$ , the half-rank  $\rho$ , and the number of independent equations  $\gamma$ . An attempt is made to obtain a set of inequalities which must be satisfied by these four invariants for a given system; and further, such that for any set of positive integers satisfying the set of inequalities, at least one pfaffian system having these numbers for invariants exists. It is shown that for any system

$$\gamma + 2\rho \leq p \leq \gamma + \gamma\rho + \sigma.$$

If  $\rho = \sigma$  the inequalities

$$\gamma + 2\rho \leq p \leq \gamma + \gamma\rho + \rho$$

form a complete set as defined. In the particular case  $\rho = 1$ , it is shown that

$$(\sigma - 1)(\sigma - 2) = 0$$

and that if  $\sigma = 2$ ,  $p = \gamma + 3$ .

*Associated Algebraic and Partial Differential Equations.* JOSEPH A. GREENWOOD.

We are concerned with algebraic equations of the form

$$\sum_0^n a_{i_1 \dots i_n}^{\alpha} x_1^{i_1} \cdots x_n^{i_n} = 0$$

and the associated partial differential equations where each term is replaced by the partial derivative of  $u$  with respect to the variables in that term. Using the products of  $x$ 's into the algebraic system to correspond to taking derivatives in the other, we show the algebraic system to be inconsistent if and only if the general solution of its associated one is  $u = 0$ , and secondly, that the general solution of the partial differential equation system is a non-zero polynomial if and only if

$$x_1 = \cdots = x_n = 0$$

is the solution of its associated system.

*On the Matric Equations  $P(A, X) = 0$  and  $P(X) = A$ .* E. T. BROWNE.

Let  $A$  be a given square matrix of order  $n$ , and let  $F_i(A)$  ( $i = 0, \dots, m$ ) be given polynomials in  $A$  with scalar coefficients. The purpose of this paper is to investigate the existence of square matrices  $X$  of order  $n$  satisfying the equation

$$P(A, X) = \sum_{i=0}^m F_i(A) X^{m-i} = 0.$$

In the particular case where  $F_i(A)$  ( $i = 0, \dots, m-1$ ) reduce to constants  $p_i$  and  $F_m(A) = p_m - A$ , the above equation reduces to the special case

$$P(X) = A.$$

In this paper we consider only such matrices  $X$  which are expressible as polynomials in  $A$ , and it is shown that the principal *idempotent* and

*nilpotent* matrices associated with  $A$  lend themselves very readily to a simple and elegant solution of the problem.

*The Isothermal Elongation of a Stretched Rubber Band* (Lantern).

MILTON L. BRAUN.

An ordinary stationer's band was suspended in an electrically controlled heating tube of sufficient length to insure uniform temperature over the fully stretched length of the band. The temperature was held at  $38 \pm 1^\circ\text{C}$ . A 500 g. weight was attached to the band and lowered at a rate of about 1 cm/sec. Without load the band had a length of 6.12 cm. At the moment the full load was accepted by the band its instantaneous length was observed to be 30.12 cm, showing an elongation of 24.00 cm. or 392 per cent of its original length. In one min the elongation had become 410 per cent, in one hr 435 per cent, in one day 475 per cent, in 10 days 518 per cent, and in 20 days 538 per cent. The data conform to the power law relation

$$E \text{ equals } 24.00 \text{ plus } 2.66t^{0.195}$$

where  $E$  is the elongation in cm beyond the original length of the band and where  $t$  is the time in hours from the application of the load. This relationship holds within a deviation of  $\pm .049$  cm. or 0.15 per cent for 115 observations from hours 1 to 474 when the last observation was made. The deviation for fractions of an hour is greater.

*The Infrared Absorption Spectra of Acetic Acid and Acetic Anhydride.*

E. K. PLYLER and E. S. BARR.

Acetic acid and acetic anhydride show bands in the regions of 1.9, 2.3, 2.5 and  $2.8\mu$ . There is a slight variation in position and intensity but the two spectra are similar. In the region of  $5.5\mu$  there is an intense band in the acetic anhydride spectrum. When water is present acetic acid has a strong band at  $5.7\mu$ . A study of the intensities of these two bands made it possible to determine the time of formation of acetic acid from the anhydride and water. When 1 mole of water and 1 mole of anhydride were kept at  $70^\circ\text{C}$ , 50 per cent of the anhydride had reacted in 45 minutes. At  $26^\circ\text{C}$  the change required approximately 12 hrs. Other factors being constant, increasing the mole fraction of water increases the rate of reaction, and decreasing the mole fraction of water decreases the rate of reaction.

*On the Half-lives of Potassium, Rubidium, Neodymium, and Samarium.*

ARTHUR RUARK and KARL H. FUSSLER.

The long apparent half-lives of K, Rb, and Nd are in striking disagreement with theory. To relieve this discrepancy, at least in part, the suggestion has often been made that their activities are due to isotopes of small abundance, having half-lives small in comparison with the apparent ones. Using data on the relative abundance of the elements, it is shown that the half-life of the active fraction of K is greater than  $10^7$  years, and that the active fractions of Rb, Nd, and Sm have half-lives greater than  $10^8$  years. It is pointed out that these activities may be caused by small radioactive fractions of well-known isotopes; RaD and stable Pb 210 constitute a similar case. Data are presented which show that it is possible for the active portions of Nd and Sm to be genetically connected.

*Gassing-Voltage-Gravity-Temperature Relationships in the Lead-Acid Storage Cell.* H. D. CROCKFORD and W. R. SINK.

The single electrode potentials and the voltage of the cell have been determined at various temperatures and acid gravities for the lead-acid storage cell during the gassing phase of the cell charge. The data secured add greatly to the knowledge of the gassing characteristics of this type of cell.

*An Unexpected Observation on the Products of the Hydrolysis of Casein.*  
E. W. MCCHESNEY

In the process of concentrating a solution of the barium salts of the amino acids obtained by the hydrochloric acid hydrolysis of casein, it was observed that a precipitate began to form while the solution was still quite dilute. Since none of the amino acids have been reported to have very insoluble barium salts (if we except aspartic acid), this precipitate seemed worthy of investigation. The barium was removed quantitatively; the amino acids in the filtrate were converted to their copper salts, and it was found that a large fraction of these was insoluble in water. This fraction was taken up in dilute acid, the copper was removed by means of hydrogen sulfide, and the filtrate from the cupric sulfide was evaporated to a syrup. The syrup was taken up in absolute alcohol, and was almost completely soluble. On evaporation of the alcoholic solution a waxy solid was obtained; its properties were then made the subject of further study.

The material was clearly aromatic in nature as shown by strongly positive xanthoproteic and diazo tests, yet the absence of tyrosine, tryptophane, and histidine could be demonstrated by specific qual-

tative tests. Its nitrogen was entirely in the amino form, and sparingly soluble copper and barium salts could readily be prepared. The substance was strongly acidic, took up bromine readily, and reacted apparently by substitution. These and other observations made upon the material are unexpected in the light of our present knowledge of the composition of casein, since none of the known amino acids, or seemingly any combination of them, could account for the observations.

*A Color Test for the Identification of Mono-, Di-, and Trinitro Compounds.*

R. W. BOST and FRANK NICHOLSON.

One-tenth gram of a nitro body of the benzene series is dissolved in 10 cc of acetone; and 3 cc. of a 5 per cent solution of sodium hydroxide is added to it. At this point, mononitro compounds produce no color; dinitro compounds produce a purplish blue; while trinitro compounds produce a blood-red color. The presence of an amino, enolic, or a substituted amino group, interferes with the test. Acylation of the amino and enolic groups does not alter the inhibiting effect of these groups; but alkylation alters the inhibiting effect of an enolic group, though not of an amino group. In cases of a richly substituted nucleus, the typical color is not produced. The steric effect of the isomeric dinitrobenzenes is very noticeable.

# CONSTITUTION OF THE NORTH CAROLINA ACADEMY OF SCIENCE

*(Revised to date)*

## ARTICLE I

### NAME AND OBJECT

*Section 1.* The name of this organization shall be the "North Carolina Academy of Science."

*Section 2.* The objects of the Academy shall be to promote study and scientific research and to furnish, so far as practicable, a means of publication of such articles as may be deemed worthy.

## ARTICLE II

### MEMBERSHIP AND DUES

*Section 1.* Any person actively interested in science or the promotion of science, may, upon nomination by two members, be elected a Member of the Academy by a majority vote of the Executive Committee, and shall be entitled to all privileges of the Academy.

*Section 2.* The initiation fee shall be \$2.00, payable in advance, and there shall be no annual dues for the first year.

*Section 3.* The annual dues for old members shall be \$2.00, and any person in arrears at the date of the annual meeting forfeits all privileges of the Academy.

*Section 4.* Any public spirited person donating one hundred dollars or more to the Academy may be elected a Patron of the Academy and shall be entitled to full privileges of membership.

## ARTICLE III

### OFFICERS

*Section 1.* The officers of the Academy shall be a President, Vice-President, Secretary-Treasurer, and an Executive Committee of six including the President, Vice-President, and Secretary, of which three shall constitute a quorum. The President and Vice-President shall be elected for one year. The Secretary-Treasurer, and three members

of the Executive Committee for three years, one of these three members to be elected each year. All officials shall be elected, by ballot, by majority vote.

*Section 2.* The duties of all officers shall be such as usually pertain to such positions. The term of office shall begin with the adjournment of the meeting at which the elections are held and shall expire with the adjournment of the next regular annual meeting.

#### ARTICLE IV

##### REPRESENTATIVES

*Section 1.* The Academy representative to the American Association for the Advancement of Science shall be elected for a two year period.

#### ARTICLE V

##### MEETINGS

*Section 1.* The time and place of all meetings shall be determined by the Executive Committee, but there shall be at least one meeting annually for the presentation and discussion of papers, and at least one business meeting annually.

*Section 2.* Two weeks notice shall be given of all meetings, and those present at such meetings shall constitute a quorum.

#### ARTICLE VI

##### PUBLICATIONS

*Section 1.* The official organ of the Academy shall be the Journal of the Elisha Mitchell Scientific Society, published at the University of North Carolina. The Editor of the Journal and the Secretary of the Academy shall compose the editorial board for the Academy, subject to the general control of the Executive Committee of the Academy.

#### ARTICLE VII

##### AMENDMENTS

*Section 1.* This constitution may be amended by a two-thirds vote of those present at any regular meeting: Provided, that such amendments be submitted in writing to the Executive Committee at least two weeks before the meeting at which action is to be taken.

## BY-LAWS

1. The Executive Committee shall fill all vacancies occurring between meetings of the Academy.
2. Upon the written request of three or more members, the Secretary shall call a meeting of the Executive Committee, to consider such matters as may be laid before it, said meeting to take place within ten days from the time the request is submitted.
3. All elections to membership shall apply to the current *calendar year*, and no annual fee shall be collected for the year of such election.
4. The application for membership shall be accompanied by the initiation fee (\$2.00), the same to be returned to the applicant should he not be elected.
5. Yearly dues regularly become payable on January 1st of each year.
6. The Secretary-Treasurer, during his term of office, shall not be liable for annual dues, and his necessary expenses in attending the regular meetings shall be defrayed from the treasury of the Academy.

OFFICERS OF THE NORTH CAROLINA ACADEMY OF  
SCIENCE, 1902-1936

1902

<i>President</i> .....	W. L. POTEAT
<i>Vice-President</i> .....	T. G. PEARSON
<i>Secretary-Treasurer</i> .....	F. SHERMAN, JR.

1903

<i>President</i> .....	C. W. EDWARDS
<i>Vice-President</i> .....	C. E. BREWER
<i>Secretary-Treasurer</i> .....	F. SHERMAN, JR.

1904

<i>President</i> .....	CHAS. BASKERVILLE
<i>Vice-President</i> .....	J. I. HAMAKER
<i>Secretary-Treasurer</i> .....	F. SHERMAN, JR.

1905

<i>President</i> .....	F. L. STEVENS
<i>Vice-President</i> .....	J. F. LANNEAU
<i>Secretary-Treasurer</i> .....	F. SHERMAN, JR.

1906

<i>President</i> .....	J. F. LANNEAU
<i>Vice-President</i> .....	TAIT BUTLER
<i>Secretary-Treasurer</i> .....	F. L. STEVENS

1907

<i>President</i> .....	COLLIER COBB
<i>Vice-President</i> .....	J. L. LAKE
<i>Secretary-Treasurer</i> .....	F. L. STEVENS

1908

<i>President</i> .....	T. G. PEARSON
<i>Vice-President</i> .....	W. C. COKER
<i>Secretary-Treasurer</i> .....	E. W. GUDGER

1909

<i>President</i> .....	TAIT BUTLER
<i>Vice-President</i> .....	J. J. WOLFE
<i>Secretary-Treasurer</i> .....	E. W. GUDGER

1910

<i>President</i> .....	W. C. COKER
<i>Vice-President</i> .....	W. H. PEGRAM
<i>Secretary-Treasurer</i> .....	E. W. GUDGER

1911

<i>President</i> .....	W. H. PEGRAM
<i>Vice-President</i> .....	W. S. RANKIN
<i>Secretary-Treasurer</i> .....	E. W. GUDGER

1912

<i>President</i> .....	H. V. WILSON
<i>Vice-President</i> .....	W. A. WITHERS
<i>Secretary-Treasurer</i> .....	E. W. GUDGER

MEMBERS OF THE NORTH CAROLINA ACADEMY OF  
SCIENCE, 1935

	DEGREES	INSTITUTION NOW IN	DEPARTMENT NOW IN
Abell, C. A.....	M.F.	U.S.F.S.	Ap. F.E.S.
Abell, Mrs. C. A.....	B.S.	U.S.F.S.	Ap. F.E.S.
Addoms, Ruth M.....	Ph.D.	D.U.	Bo.
Anderson, D. B.....	Ph.D.	S.	Bo.
Arbuckle, H. B.....	Ph.D.	D.C.	C.
Barber, Lena A.....	M.S.	M.	B.
Barrow, Elva.....	M.S.	W.C.	C.
Bartlett, Grady W.....	B.S.	S.	P.
Barton, Helen.....	Ph.D.	W.C.	M.
Beck, Clifford K.....	A.B.	H.S.	S. & M.
Beers, C. D.....	Ph.D.	U.N.C.	Z.
Bigelow, L. A.....	Ph.D.	D.U.	C.
Billings, W. Dwight.....	M.A.	D.U.	Bo.
Black, C. S.....	Ph.D.	W.F.	C.
Blomquist, H. L.....	Ph.D.	D.U.	Bo.
Bloxam, Percy.....	M.S.	S.	A.
Boggess, W. R.....	A.B.	D.U.	Bo.
Boliek, Irene.....	M.A.	U.N.C.	Z.
Bookhout, C. G.....	Ph.D.	D.U.	Z.
Boomhour, Elizabeth.....	M.A.	M.	B.
Boomhour, J. G.....	M.A.	M.	P.
Bost, R. W.....	Ph.D.	U.N.C.	C.
Bostian, C. H.....	Ph.D.	S.	Z.
Bradbury, O. C.....	Ph.D.	W.F.	B.
Brandt, B. B.....	Ph.D.	M.G.C.	B.
Braun, M. L.....	Ph.D.	Cat.	M. & P.
Brimley, C. S.....		A.	Ent.
Brimley, H. H.....		Mus.	
Brimley, R. F. W.....	B.S.	H.S.	S. & Ath.
Browne, E. T.....	Ph.D.	U.N.C.	M.
Buell, Jesse H.....	M.F.	U.S.F.S.	Ap. F.E.S.
Bullard, Lena.....	M.A.	H.S.	S.
Bullitt, J. B.....	{ M.A. M.D.	U.N.C.	Med.
Butts, Helen E.....	Ph.D.	Wel.	Z.
Cameron, Frank K.....	Ph.D.	U.N.C.	C.
Campbell, Eva.....	Ph.D.	G.C.	B.
Campbell, Roy J.....	C.P.H.	S.C.	B.
Carlsson, Emma V.....	Ph.D.	W.C.	Hy.

	DEGREES	INSTITUTION NOW IN	DEPARTMENT NOW IN
Carroll, Zoe Wells.....	M.A.	Ma.C.	B.
Causey, Rebecca M.....	A.B.		
Chamberlain, B. R.....	E.E.	S.B.T.	
Cleaver, Mary Conrad.....	Ph.D.	Cat.	B.
Clevenger, C. B.....	Ph.D.	S.	So.
Clevenger, W. L.....	M.S.	S.	D.
Coker, R. E.....	Ph.D.	U.N.C.	Z.
Coker, W. C.....	Ph.D.	U.N.C.	Bo.
Colby, Chas. DeWitt.....	M.D.	W.L.D.C.	Med.
Coldwell, Inez.....		W.C.	B.
Correll, Don S.....	A.B.	D.U.	Bo.
Couch, J. N.....	Ph.D.	U.N.C.	Bo.
Crittenden, Chas. V. V.....	M.A.	W.C.	B.
Crockford, H. D.....	Ph.D.	U.N.C.	C.
Cruse, Emmett E.....	A.B.	Cat.	P.
Culbertson, J. W.....	M.A.	U.N.C.	Med.
Cunningham, Bert.....	Ph.D.	D.U.	Z.
Dearborn, Donald C.....	M.A.	D.U.	M.
Deatrict, Eugene P.....	Ph.D.	U.S.D.A.	So.E.
Denson, Lee A.....		U.S.W.B.	Sec.
Derieux, J. B.....	Ph.D.	S.	P.
Dixon, A. A.....	Ph.D.	S.	P.
Dodson, C. F.....	M.S.	C.C.	B.
Douglas, J. M.....		D.C.	P.
Dressel, F. G.....	Ph.D.	D.U.	M.
Duncan, Wilbur H.....	M.A.	D.U.	Bo.
Edmister, F. H.....	Ph.D.	U.N.C.	C.
Edwards, C. W.....	M.A.	D.U.	P.
Edwards, Margaret M.....	M.A.	W.C.	H.E.
Eliason, Nancy.....	M.A.	H.S.	B.
Eller, Frank.....		Cat.	
Elliott, W. W.....	Ph.D.	D.U.	M.
Emory, Samuel T.....	M.A.	U.N.C.	G.
Evinger, Edgar L.....	M.S.	U.S.D.A.	So.E.
Foster, Norman B.....	M.S.	W.C.	
Frink, Horace W.....	M.D.	U.N.C.	
Fritz, R. L.....		L.R.	
Fulcher, H. E.....	M.S.	D.C.	P.
Fulton, B. B.....	Ph.D.	S.	Ent.
Fultz, Chester Ray.....		Cat.	
Fussler, Karl H.....	Ph.D.	U.N.C.	P.
Garren, G. M.....	M.S.	S.	Ag.
George, W. C.....	Ph.D.	U.N.C.	Med.
Ginnings, P. M.....	Ph.D.	G.C.	C.
Githens, Sherwood.....	M.A.	U.N.C.	P.
Givler, J. P.....	M.A.	W.C.	B.
Glenn, Mrs. Jane C.....	M.S.	F.M.C.	C.

	DEGREES	INSTITUTION NOW IN	DEPARTMENT NOW IN
Graham, Minnie A.....	Ph.D.	Q.C.	P. & C.
Greenwood, J. A.....	Ph.D.	D.U.	M.
Grimsley, Gertrude.....	M.A.	H.S.	
Gross, P. M.....	Ph.D.	D.U.	C.
Grove, C. S.....	Ch.E.	S.	C.E.
Gudger, E. W.....	Ph.D.	A.M.	I.
Hall, Earl H.....	M.A.	W.C.	B.
Hall, F. G.....	Ph.D.	D.U.	Z.
Halverson, J. O.....	Ph.D.	Exp.	N.
Harbison, T. G.....		U.N.C.	Bo.
Hard, Walter L.....	A.B.	D.U.	Z.
Hargitt, George T.....	Ph.D.	D.U.	Z.
Harkema, Reinard.....	Ph.D.	E.C.	B.
Harmon, Fannie R.....	M.A.	Cat.	B.
Harris, Mildred.....	M.A.	W.C.	Hy.
Hatley, C. C.....	Ph.D.	D.U.	P.
Hauser, C. R.....	Ph.D.	D.U.	C.
Heck, C. M.....	M.A.	S.	P.
Hickson, A. O.....	Ph.D.	D.U.	M.
Hildebrand, Samuel F.....	Ph.D.	U.S.B.F.	Wash.
Hill, Douglas G.....	Ph.D.	D.U.	C.
Holl, Frederick J.....	Ph.D.	U.B.	Z.
Holland, Alma.....	A.B.	U.N.C.	Bo.
Holmes, J. S.....	M.F.	C. & D.	F.
Hopkins, Dwight L.....	Ph.D.	D.U.	Z.
Howe, M. Dorisse.....	Ph.D.	Q.C.	B.
Huddle, John W.....	Ph.D.	U.N.C.	G.
Hunt, Melba.....	A.B.	M.	B.
Isbell, Robert N.....	Ph.D.	W.F.	C.
Ives, J. D.....	M.A.	C.N.	B.
Johnson, Wm. R.....		U.N.C.	G.
Jones, Ivan D.....	Ph.D.	S.	Ho.
Klenner, Frederick.....		D.U.	Med.
Korstian, C. F.....	Ph.D.	D.U.	F.
Kramer, Paul J.....	Ph.D.	D.U.	Bo.
Lake, J. L.....	M.A.	W.F.	P.
Lancaster, F. W.....	C.E.	S.	P.
Lasley, J. W.....	Ph.D.	U.N.C.	M.
Latham, Dennis H.....	M.A.	U.S.F.S.	P.P.
Lay, Mrs. George B.....	M.A.		
Ledbetter, Ida B.....	M.A.	Ap. S.	B.
Lehman, S. G.....	Ph.D.	S.	Bo.
Lineberry, R. A.....	Ph.D.	U.S.D.A.	So.
Ljung, Harvey A.....	Ph.D.	Gu.	C.
Lutz, J. F.....	Ph.D.	S.	So.
Lyon, Scott Cary.....	D.Sc.	D.C.	B.
MacCarthy, Gerald R.....	Ph.D.	U.N.C.	G.
MacNider, W. de B.....	M.D.	U.N.C.	Med.

	DEGREES	INSTITUTION NOW IN	DEPARTMENT NOW IN
McCampbell, John C.....	B.S.	U.N.C.	G.
McNutt, Dorothea R.....	B.S.	G.C.	B.
Mackie, E. L.....	Ph.D.	U.N.C.	M.
Mann, H. B.....	M.D.	U.N.C.	Med.
Manning, I. H.....	M.D.	U.N.C.	Med.
Matthews, Velma.....	Ph.D.	Cok.	B.
Meares, J. S.....	M.S.	S.	P.
Mebane, W. N.....	M.A.	D.C.	M.
Merwin, Marion I.....	A.B.	Cat.	B.
Metcalf, Z. P.....	D.Sc.	S.	Z. & Ent.
Middlekauff, Hugh E.....		Cat.	P.
Miles, E. R. C.....	Ph.D.	D.U.	M.
Miller, James Kyle.....	M.A.	H.S.	B.
Mitchell, T. B.....	D.Sc.	S.	Z.
Morgan, Karl Z.....	Ph.D.	L.R.	P.
Norburn, Martha E.....	Ph.D.		
Olpin, A. R.....	Ph.D.	K.M.	R.
Oosting, H. J.....	Ph.D.	D.U.	Bo.
Pearse, A. S.....	Ph.D.	D.U.	Z.
Pegram, Annie M.....	M.A.	G.C.	M.
Perry, H. S.....	Ph.D.	D.U.	Bo.
Perry, Louise W.....	M.D.		
Petty, Mary.....	B.S.	W.C.	C.
Plyler, E. K.....	Ph.D.	U.N.C.	P.
Poole, Frazer G.....		Cat.	B.
Poole, R. F.....	Ph.D.	S.	Bo.
Porter, W. L.....	M.A.	D.C.	B.
Poteat, W. L.....	M.A.	W.F.	B.
Powell, T. E.....	Ph.D.		
Preston, Carleton E.....	Ph.D.	U.N.C.	Ed.
Prouty, Wm. F.....	Ph.D.	U.N.C.	G.
Prytherch, H. F.....	Ph.D.	U.S.B.F.	Beau.
Purdom, Emil G.....	Ph.D.	Gu.	P.
Ramsey, George G.....	Ph.D.	Cat.	C.
Randolph, E. E.....	Ph.D.	S.	C.E.
Raynal, Charles E.....	D.D.	P.C.	St.
Reddish, Paul S.....	A.B.	H.S.	
Reed, Mrs. Mildred S.....	M.A.	D.U.	Bo.
Reed, John F.....	M.A.	D.U.	Bo.
Reid, W. A.....	B.S.	S.	C.
Rhodes, L. B.....	M.S.	A.	F. & O.
Roberts, John H.....	Ph.D.	D.U.	M.
Robinson, Mrs. W. F.....	M.A.	M.H.C.	M.
Ruark, Arthur E.....	Ph.D.	U.N.C.	P.
Ryburn, Wm. O.....		Cat.	B.
Satterfield, G. H.....	M.A.	S.	C.
Saylor, John M.....	Ph.D.	D.U.	C.
Schaeffer, Florence L.....	M.A.	W.C.	C.

	DEGREES	INSTITUTION NOW IN	DEPARTMENT NOW IN
Shaftesbury, A. D.	Ph.D.	W.C.	Z.
Sherman, Franklin	M.S.	Clem.	Z. & En.
Sherwood, F. W.	Ph.D.	Exp.	N.
Shunk, I. V.	M.A.	S.	B.
Sink, Woodford G.	A.B.	Cat.	
Smith, Arlie R.	M.A.	Ap. S.	C.
Smith, Budd E.	A.B.		
Smith, F. F.	A.B.	Y.	F.
Smith, F. H.	M.S.	Exp.	N.
Spangler, Helen V.	M.S.	D.U.	Bo.
Speas, W. E.	Ph.D.	W.F.	P.
Stiles, C. W.	{ M.D. Ph.D.	S.I.	
Strong, Cornelia	M.A.	W.C.	M.
Summerell, Frances	M.A.	W.C.	B.
Taylor, O. B.	M.A.	S.P.	W.
Thiel, Albert F.	Ph.D.	W.C.	Bo.
Thies, O. J.	M.A.	D.C.	C.
Thomas, J. M.	Ph.D.	D.U.	M.
Tiedeman, John A.	Ph.D.	W.C.	P.
Totten, H. R.	Ph.D.	U.N.C.	Bo.
Traver, Jay R.	Ph.D.	C.U.	R.
Van Note, Wm. G.	M.S.	S.	C.E.
Vardell, Mary Linda	M.A.	F.M.C.	B.
Vosburgh, W. C.	Ph.D.	D.U.	C.
Warfield, Calvin N.	Ph.D.	W.C.	P.
Webb, T. N.	A.B.	D.U.	Fl.
Wells, B. W.	Ph.D.	S.	Bo.
Wells, Mrs. B. W.	B.S.	H.S.	B.
Wentz, B. A.	Ph.D.	Cat.	Ps.
Wheeler, A. S.	Ph.D.	U.N.C.	C.
Whitford, L. A.	M.S.	S.	Bo.
Williams, C. B.	M.S.	S.	Ag.
Williams, L. F.	Ph.D.	S.	C.
Williams, Maude	M.A.	W.C.	Ps.
Williams, Myra A.	M.A.	P.J.	S.
Willis, L. G.	M.S.	S.	Ag.
Willoughby, Julius E.	C.E.	A.C.L.	E.
Wilson, H. V.	Ph.D.	U.N.C.	Z.
Wilson, R. N.	M.S.	D.U.	C.
Winston, Lula G.	Ph.D.	M.	C.
Wolf, F. A.	Ph.D.	D.U.	Bo.
Wood, Vernon	M.S.	M.H.C.	C. & P.
Yarbrough, Mary E.	M.S.	M.	C.
Yoder, M. C.	M.A.	L.R.	B.
Zoeller, E. V.	{ P.D. Ph.G.	Phar. B.	

*Code under Institution*

A., N.C. Department of Agriculture  
A.C.L., Atlantic Coast Line Rail Road  
A.M., American Museum of Natural History  
Ap.S., Appalachian State Teachers College, Boone  
Cat., Catawba College  
C.C., Campbell College  
C. & D., N.C. Department of Conservation & Development  
Clem., Clemson College  
C.N., Carson & Newman College  
Cok., Coker College  
C.U., Cornell University  
D.C., Davidson College  
D.U., Duke University  
E.C., Elon College  
Exp., State Experiment Station  
F.B.S., U. S. Fisheries Biological Station  
F.M.C., Flora McDonald College  
G.C., Greensboro College  
G.S., N.C. Geological Survey  
Gu., Guilford College  
H.S., High School  
K.M., Kendall Mills  
L.R., Lenoir Rhyne College  
M., Meredith College  
Ma.C., Maryville College  
M.G.C., Middle Georgia College, Cochrane, Ga.  
M.H.C., Mars Hill College  
Mus., State Museum  
P.C., Presbyterian Church  
Phar.B., North Carolina Board of Pharmacy  
P.J., Peace Junior College  
Q.C., Queen's-Chicora College  
R.S.C., Rockefeller Sanitary Commission  
S., N.C. State College  
S.B.T., Southern Bell Telephone Company  
S.C., Salem College  
S.I., Smithsonian Institution  
S.P., State Parks  
U.B., University of Buffalo  
U.N.C., University of North Carolina  
U.S.B.F., U. S. Bureau of Fisheries  
U.S.D.A., U. S. Department of Agriculture  
U.S.F.S., U. S. Forest Service  
U.S.W.B., U. S. Weather Bureau  
W.C., Woman's College of the University of North Carolina  
Wel., Wellesley College  
W.F., Wake Forest College

W.L.D.C., The William LeRoy Dunn Clinic, Asheville  
Y., Yale University

*Code under Department*

- A., Agriculture
- Ag., Agronomy
- Ap. F.E.S., Appalachian Forest Experiment Station
- Ath., Athletics
- B., Biology
- Beau., Beaufort Station
- Bo., Botany
- C., Chemistry
- C.E., Chemical Engineering
- D., Dairying
- E., Engineering
- Ed., Education
- Ent., Entomology
- Exp., Experiment Station
- F., Forestry
- Fl., Floriculture
- F. & O., Food and oil
- G., Geology
- H.E., Home Economics
- Ho., Horticulture
- Hy., Hygiene
- M., Mathematics
- Med., Medical
- N., Nutrition
- P., Physics
- P.P., Plant Pathology
- Ps., Psychology
- R., Research
- S., Science
- Sec., N.C. Section
- So., Soils
- So.E., Soil Erosion
- St., Statesville
- W., Wildlife
- Wash., Washington, D. C.
- Z., Zoology

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC  
SOCIETY

OCTOBER 9, 1934, TO MAY 14, 1935

354TH MEETING, OCTOBER 9, 1934

H. D. CROCKFORD: *Certain Thermodynamic Studies of Lead-Acid Storage Cells.*

The heat balance relationships in the operation of the lead-acid storage cells have been studied and a thermodynamic explanation of the heating characteristics worked out. The maximum heating occurs when the gassing is most pronounced in the latter stages of the charge.

W. C. GEORGE: *The Rôle of Blood Cells in Excretion in Ascidians.*

355TH MEETING, NOVEMBER 13, 1934

H. M. BURLAGE and CHARLES E. BRADY: *The Official Sulfur Ointments and their Assay.*

The properties and uses of elemental sulphur and its three official ointments were discussed as well as the proposed assays for the same, which to date have been very unsatisfactory. The following modifications of Shulek's methods<sup>1</sup> have been found to be quite satisfactory and rapid:

Weigh accurately into a small beaker (50 cc. capacity) a sample of ointment equivalent to 2-4 centigrams of sulphur. Scatter on the sample 0.2 g. KCN, add 8-10 drops of water and 15 cc acetone and evaporate to dryness at a temperature sufficiently high to melt the ointment. Repeat the process of warming with acetone and subsequent evaporation twice using each time 5 cc. of the solvent. Dissolve the residue in water and filter through a small filter. Heat the fatty material remaining in the beaker with 5 cc. of water almost to boiling; cool somewhat and pass the aqueous liquid through the same filter. Repeat this procedure 3-4 times. The combined filtrates are received in a 125 cc. glass-stoppered Erlenmeyer flask, add 1 g. boric acid, and boil gently for ten

<sup>1</sup> E. Shulek, Pharm. Monatsh., 14, 228-9 (1933).

E. Shulek, Z. Analyt. Chem., 62, 337 (1923).

minutes. (If a clear filtrate is not obtained add the boric acid first, and in some cases 0.5 g. coarse pumice, boiling 10 minutes and then filtering and wash as described above.) Acidify the cooled solution (amounting to 50–60 cc.) with 5 cc. phosphoric acid (20 per cent), add bromine water dropwise until the solution is distinctly yellow. Add phenol (5 per cent) until the solution is decolorized. Shake well and set aside for  $\frac{1}{4}$  hour. Add 0.5 gm. KI and allow to stand in the dark for  $\frac{1}{2}$  hour keeping the flask tightly stoppered and then titrate with 0.1 N  $\text{Na}_2\text{S}_2\text{O}_3$  using FRESH starch as an indicator.

$$1 \text{ cc. } 0.1 \text{ N } \text{Na}_2\text{S}_2\text{O}_3 = 0.01603 \text{ g. sulphur.}$$

**WALTER GORDY: *The Infrared Absorption of Solutions of Hydroxides and Hydrolyzing Salts.***

A study has been made of aqueous solutions of  $\text{NaOH}$ ,  $\text{KOH}$ ,  $\text{LiOH}$ ,  $\text{ZnCl}_2$ ,  $\text{ZnBr}_2$ ,  $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{NaC}_2\text{H}_3\text{O}_2$ ,  $\text{Na}_2\text{B}_4\text{O}_7$ ,  $\text{Na}_2\text{SiO}_3$ , and  $\text{Al}_2(\text{SO}_4)_3$  in the region from  $0.6\mu$  to  $6.6\mu$ . Bands were observed at  $0.75\mu$ ,  $0.79\mu$ ,  $0.87\mu$ ,  $1.04\mu$ ,  $1.22\mu$ ,  $1.81\mu$ ,  $2.30\mu$ ,  $2.60\mu$ ,  $3.65\mu$ , and  $5.2\mu$  in the hydroxide solutions. These bands were at approximately the same positions for all the hydroxides, and the more intense bands were observed for concentrations down to 0.1 normal. The salt solutions were found to have bands in the same regions as the hydroxides and, in addition, bands were observed in the regions of  $4.5\mu$  and  $5.6\mu$ . Bands had been previously observed at  $5.6\mu$  in acid solutions. The bands in the region of  $4.5\mu$  were not present in either hydroxide or acid solutions and are to be attributed to energy levels characteristic of hydrolyzing salts.

From the results of the study of hydrolyzing salts, it was found possible to draw definite conclusions about the hydroxide bands at  $1.81\mu$ ,  $2.30\mu$ ,  $2.60\mu$ ,  $3.65\mu$ , and  $5.2\mu$  and about the band in the region of  $5.6\mu$  characteristic of acid solutions. For salt solutions which gave acid reaction the absorption was great in the regions of  $1.81\mu$ ,  $2.60\mu$ ,  $3.65\mu$ , and  $5.2\mu$ , and the absorption in the regions of  $2.30\mu$  and  $5.6\mu$  was less intense, whereas, for salts which yield basic solutions, the bands at  $2.30\mu$  and  $5.6\mu$  were intense, and the absorption in the regions of  $1.81\mu$ ,  $2.60\mu$ ,  $3.65\mu$ , and  $5.6\mu$  was less intense. This intensity variation indicates that the hydroxide bands at  $1.81\mu$ ,  $2.60\mu$ ,  $3.65\mu$ , and  $5.2\mu$  are characteristic of the hydroxide molecule in solution, and that the band at  $2.30\mu$  is characteristic of the hydroxide ion. This variation indicates, also, that the acid band at  $5.6\mu$  is characteristic of the hydrated acid molecule rather than the H ion.

The bands at  $2.30\mu$ ,  $3.65\mu$ , and  $5.2\mu$  were considered as fundamentals, and it was found possible to classify all other bands observed in hydroxide solutions as harmonics of these bands.

### 356TH MEETING, DECEMBER 11, 1934

J. N. COUCH: *Natural Hybrids of Septobasidium*.

ENGLISH BAGBY: *The Genesis of an Hysterical Symptom*.

It has long been known that many types of motor and sensory disorders as well as complete disease complexes, such as epilepsy, may operate on an organic or on a functional basis. Disorders of the latter sort are called hysterical and careful study usually reveals that they have the status of psychological reactions to situations which exist or have existed in the lives of the patients.

Hysterical phenomena appear to arise through the operation of three distinct forms of processes, as follows:—

1. An individual may persistently engage in phantasy thinking and this thinking may find unintended expression in a sustained abnormal posture. For instance, a patient, after disappointment in a love affair with a cobbler, now engages in romantic phantasies about the man and exhibits a contracture which simulates his posture when at work.

2. If a person has suffered a paralysis in connection with an intensely emotional episode, the paralysis may persist after its original organic basis has entirely ceased to be present. This is known as reintegration and was of common occurrence in the recent war. It is reported that a certain soldier became paralysed when a high explosive shell burst near him. He remained paralysed as long as he remained near the front where he could hear the sounds of explosions.

3. In most cases, hysterical symptoms have a utility; that is, through them some positive advantage is secured or some unsatisfactory life situation is avoided. A young woman exhibited hysterical pains in her chest and it appeared that through this "device" she was able to avoid the burden of excessive industrial work and also force her parents to permit her to enjoy the company of young men, a privilege which had not previously been granted to her. During a visit to a distant city, the symptoms disappeared, presumably because they were "unnecessary" under the circumstances. Upon her being summoned home several weeks later, the pains reappeared. Treatment consisted in persuading the patient to establish an independent life away from home, to take a position requiring no more than reasonable hours of labor, and to have friends as she desired. This mode of life was a substitute for the hysteria and there has been no remission of symptoms in several years.

## 357TH MEETING, JANUARY 8, 1935

J. W. LASLEY, JR.: *On the Integration of Monge's Differential Equation.*

This differential equation was attributed to Monge by Boole. However Sylvester upon looking into the validity of this claim was unable to find any trace of the equation either in the printed work or manuscripts of Monge. Nor were the compatriots of Monge able to locate the equation. After much stir it was authenticated by an American, Beman. The present study concerns itself with a direct, and relatively simple integration of the equation. The technique involves expressing the differential equation in the form of a third order determinant, which after applications of elementary transformations leads to another third order determinant seen to be a Wronskian. By means of well known properties of this functional determinant an integration is then effected, leading to the conics as the system of integral curves.

W. F. PROUTY: *Geology of Coastal Plain.*

The Atlantic Coastal Plain from its northern terminus in Massachusetts to its passage into the Gulf Coastal Plain in Alabama is everywhere composed chiefly of unconsolidated sands, clays and marls. These stratified deposits dip gently toward the ocean with a variable slope but one greater than that of the Coastal Plain surface. Previous studies have shown<sup>1</sup> that the basement rock underlying the Coastal Plain has a broad arch whose axis extends across N. C. practically parallel with the Cape Fear Basin and that the Coastal Plain basement is much lower in Virginia to the northeast and in South Carolina to the southwest than is the case in North Carolina. Additional structural data concerning the Coastal Plain have been secured through magnetometer studies carried on by a field party from the University of North Carolina.<sup>2</sup> This survey demonstrated that in the northeastern part of South Carolina the Coastal Plain basement rock is more steeply inclined toward the Atlantic in the near coast area than it is farther inland and that the previously discovered buried Triassic deposits are in a well defined structural basin about 14 miles wide near Florence, S. C., and that this buried valley with its Triassic sediments can be traced by the magnetometer well into North Carolina. These structural conditions are shown on the left and front elevations of the block diagram, Figure 1. On the

<sup>1</sup> Dr. L. W. Stephenson, Bull. Geol. Soc. Am. **39**: 179, 1928.

<sup>2</sup> Party made up of W. F. Prouty, G. R. MacCarthy, and J. A. Alexander, Elisha Mitchell Sci. Soc. **49**: 20-21, 1933.

surface of this diagram is also shown the geological formations of the Coastal Plain of North Carolina. All formations marked with a K are of Cretaceous age. The lower formation marked Kt (Tuscaloosa formation) is non-marine in character and does not extend as far as the present coast line. The higher Cretaceous formations, the Eutaw (Ke) and the Ripley (Kr) are marine in character.

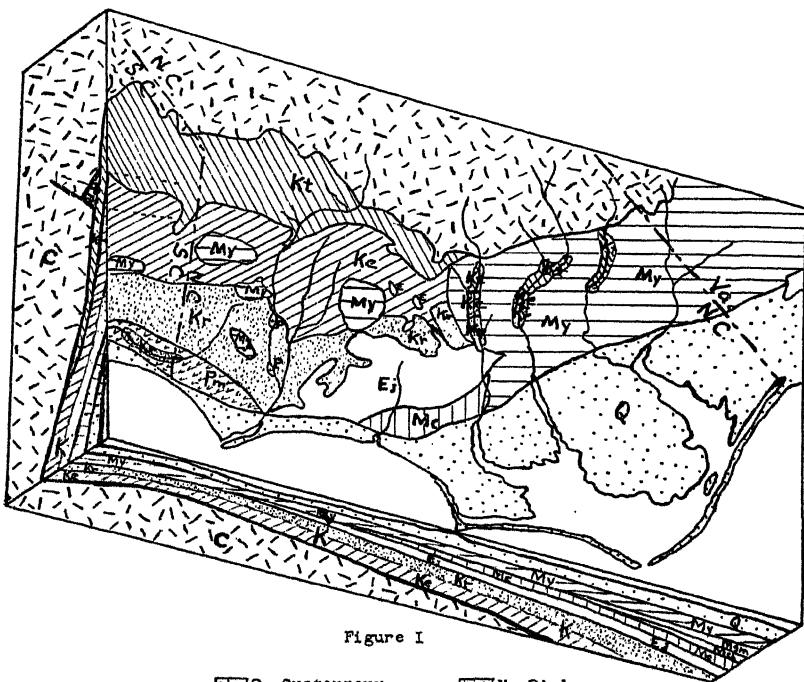


Figure 1

Q Quaternary	Kr Ripley
Pm Pliocene	Ke Eutaw
My Yorktown	Kt Tuscaloosa
Mc Calvert	T Triassic
Ej Trent	C Crystalline

The Cretaceous is best developed in the southwest half of the N. C. Coastal Plain. In the northeastern half the upper Miocene sediments cover much of the territory to the west of the Quaternary of the Pamlico and Albemarle Sound areas. In this northeastern half the Cretaceous is exposed only in places along the stream valleys. On the other hand, the upper Miocene (My) occurs in the southwestern half of the Coastal

Plain of N. C. in a few large outliers only. The Eocene (Ej) sediments are chiefly confined to the east central portion of the Coastal Plain and to a few small outliers in the western portion. One of the most interesting geological features of the Coastal Plain is the system of marine terraces having gentle oceanward slopes. This veneer of marine, sandy deposit occurs in steps or terraces which are made up along the inland border of more coarsely textured materials. These terraces represent the near shore deposits of the ocean as it stood at successively lower and lower levels during the Glacial Period. During this glacial time the coast area of N. C. must have been undergoing rather steady elevation. The old shore line which marks the ocean front at the end of Pliocene time has now an elevation of about 265' above the present sea level. With the withdrawal of ocean water to form the first great ice sheet the ocean level was probably lowered by as much as 250'-300'. During the first interglacial time the melting ice again raised the ocean level, but due to land elevation the new shore-line was lower than the old shore-line. The above process was repeated during each of four later ice invasions and retreats. Each time the flood waters returned to form a lower-level terrace on the rising Coastal Plain.

The President announced that the committee to draw up a resolution on the death of Dr. Collier Cobb was made up of Professors W. F. Prouty, W. deB. MacNider, and H. V. Wilson. Professor Prouty then read the resolution which was as follows:

DR. COLLIER COBB

The death of Professor Collier Cobb on November 28, 1934, at Chapel Hill, N. C., has taken from the Elisha Mitchell Scientific Society one of its most loyal supporters. Professor Cobb was a constant contributor to the Society's activities and publications from the time of his appointment as Assistant Professor of Geology in the University of North Carolina in 1892 until the beginning of his final illness in 1933. A striking instance of his untiring interest in the Society was his voluntary service in the compilation of new minutes to fill a gap in the records of the Society. The gap in the records embraced a period of several years and compiling the new minutes required careful work for several months.

Professor Cobb was a native of North Carolina and was noted for his devotion to his state and its institutions, but this fact did not in any way limit his keen interest in travel and in world affairs and he was nearly as well known abroad as in the United States. His Christmas

mail always brought remembrances from people of high rank in many lands. His striking personality, keen intellect, and remarkable memory, coupled with his wealth of rare anecdotes, made him a central figure in any group.

Because of his travel and great interest in peoples and customs he will, perhaps, be best remembered in the scientific world as a human geographer. In the bibliography recently published by the Elisha Mitchell Scientific Society Professor Cobb has thirty-three listed publications. Seventeen of these dealt with human geography and nine with shoreline processes and development. Although his writings cover a wide field of thought, his greatest interest was in the work of the wind in desert and shore areas as is indicated by: "Where the Wind Does the Work," "Lands and Dunes of Gascony," and "Loess Deposits of China."

The early intellectual development of Professor Cobb was remarkable. At the age of nine he began the publication of "The Home Journal" in Shelby, North Carolina. In his tenth year he made a metrical English version of Virgil's Georgics and printed this for his friends. The early talent for writing followed him in his college career. After two years spent at Wake Forest and one at the University of North Carolina, Professor Cobb took his A. B. and M. A. degrees at Harvard. While at Harvard he furnished a number of newspapers with "associated news."

Professor Cobb was one of the great pioneers of geology in North Carolina and he enjoyed a notable record as an enthusiastic and inspiring teacher, believing that the spirit of the subject was more important than the letter, and with this same appreciation many of his students have gone out into positions of responsibility and honor.

Professor Cobb was a fellow of the Geological Society of America, and member of many societies, including the American Association for the Advancement of Science, Association of American Geographers, Boston Society of Natural History, American Institute of Mining and Metallurgical Engineers, Seismological Society of America, Elisha Mitchell Scientific Society, North Carolina Academy of Science, Sigma Xi.

Professor Cobb's knowledge of the University and of the state of North Carolina was such that he was much consulted for facts not readily obtainable elsewhere. Always a collector of books, his private library grew into one of unusual value.

The Elisha Mitchell Scientific Society has suffered a great loss by the death of Professor Collier Cobb and wishes to acknowledge and express appreciation for his active and loyal services."

## 358TH MEETING, FEBRUARY 12, 1935

C. W. BORGGMANN: *An Optical Investigation of the Passivity of Iron in Nitric and Chromic Acids.*

It is well known that polarized light undergoes a change of state upon reflection from a metallic surface, and that this change is further influenced by the presence of a surface film. It is thus possible to determine whether or not the passivity of iron in nitric and chromic acids is due to a surface film, and finally, it is possible to measure the approximate thickness and refractive index of such a film if present.

Measurements were made on (a) fairly pure iron, (b) eutectoidic steel, and (c) austenitic stainless steel while immersed in either concentrated nitric acid or 0.01 M chromic acid. The results of the tests may be summarized briefly, as below. The natural (air-formed) oxide film on iron is replaced in nitric acid by one of 25 to 35 Ång. thick when the surface is finely polished; and by one of 80 to 100 Ång. when the surface is somewhat rough. On steel, the initial film is replaced by one of 80 to 100 Ång. thick; the nature of the surface had little influence. The film formed on the stainless steel in nitric acid is extremely thin (10 Ång.) and is perfectly protective—no growth could be measured over periods of several hours. The refractive index of the films in all cases is nearly that of ferric oxide in the bulk. The films formed on iron and steel in chromic acid are approximately the same in thickness (30 to 40 Ång.). However, the refractive index is relatively low, and thus the films are believed to be partly hydrated in this case. The results of these tests give valuable support to the oxide film theory of passivity—a theory which was first put forward by Faraday, but has only been generally accepted in very recent times.

A. S. ROSE: *The Mechanism of Visceral and Referred Pain.*

The internal organs are relatively insensitive to the usual forms of stimuli, such as, cutting, pinching, burning, etc. This lack of sensibility is due to the fact that under normal conditions the afferent neurons from the viscera do not make contact in the spinal cord with secondary neurons which carry the impulses to consciousness. Under conditions of disease, however, very severe pain may be felt. The theories for the explanation for this visceral pain are discussed. Mackenzie's theory of the pain being referred to the body surface by way of the spinal nerves, due to the production of an "irritable focus" in the spinal cord is the one most generally accepted. The clinical and experimental data which have been considered to favor this theory are presented. The micro-

scopic anatomy of the spinal cord is discussed briefly to show that the visceral afferent fibers and the afferent fibers from the body surface, mediating pain, terminate in close proximity to each other in the spinal cord. It is further pointed out that there is also a functional relationship between these fibers. Recent advances in physiology have shown that a chemical agent is used in the transfer of the effects of a nerve impulse to the active tissues, in the passage of the synapses in the sympathetic ganglia, and possibly also in the central nervous system. On the basis of these facts, it is proposed that visceral and referred pain is dependent upon the production of an abnormal amount of some chemical substance at the tip of the dorsal horn of the gray matter of the spinal cord, and the diffusion of this substance to adjacent cells whose axons travel in the pathways for pain perception.

### 359TH MEETING, MARCH 12, 1935

W. C. COKER: *Parasitic Flowering Plants of North Carolina.*

Colored slides were shown of all the known flowering parasites of this state except some of the smaller members of the figwort family (Scrophulariaceae). Four of these are complete parasites, such as squaw-root and beech-drops. Six, while parasitic, are able to manufacture a part of their food because of their green leaves, such as mistletoe and buffalo-nut. Nineteen use animals which they kill for food, such as Venus's Fly-trap, pitcher plants, and bladderworts. All of these last have more or less chlorophyll and are therefore not completely dependent on animal food. Several additional slides of parasitic plants from foreign countries were shown for the remarkable peculiarities which they exhibit.

T. F. HICKERSON: Four Solutions of a Railroad Bent Problem.

### 360TH MEETING, APRIL 9, 1935

JOSEPH NISBET LeCONTE: *Some Quinoline Derivatives of 2-Amino-p-cymene.* (Under the direction of Dr. A. S. Wheeler.)

A mixture of aminocymene and nitrocymene was subjected to Cohn and Gustavson's synthetic process for making quinolines. Product, 5-isopropyl-8-methylquinoline, a yellow oil, b.230-232° at 190 mm., 175° at 35 mm. This compound is reduced by sodium and alcohol to 1,2,3,4-tetrahydro-5-isopropyl-8-methylquinoline; a pale yellow oil, b.165-167° at 27 mm. The condensation of aminocymene with paraldehyde gave 2,8-dimethyl-5-isopropylquinoline; white plates, m.78°,

b.179° at 35 mm., 170° at 25 mm. When reduced with sodium and alcohol, this compound yields 1,2,3,4-tetrahydro-2,8-dimethyl-5-isopropylquinoline; white rhombic crystals, m.65°. Aminocymene and acetylacetone condensed to form acetylacetocymidine; pale yellow oil, b.184–185° at 22 mm. This, when dehydrated with sulfuric acid, forms 2,4,8-trimethyl-5-isopropylquinoline; a yellow oil, b.177–178° at 22 mm. Ethyl acetoacetate condensed with aminocymene, at high temperatures, to produce acetoacetocymidine; long white needle crystals, m.235°. When dehydrated, this forms 2-hydroxy-4,8-dimethyl-5-isopropylquinoline; short white prismatic needles, shrink 225°, m.228–230°. A cymyl isatin was formed; orange-brown plates, m.174°. This compound failed to form cymyl atophan and cymyl-methyl cinchonic acid by the Pfitzinger method due to its decomposition by strong alkalies with the liberation of ammonia.

Reactions of these compounds with picric acid, methyl iodide, chloroplatinic acid, and other substances, were studied. The steric influence of substituents, and the nature of these substituents, have a marked influence on the reactions of quinoline compounds. Substituents in position 8 prevent these quinolines forming methyl iodide addition compounds. 5-Isopropyl-8-methylquinoline formed a picrate by the usual method, 2,8-dimethyl-5-isopropylquinoline and 2,4,8-trimethyl-5-isopropylquinoline with difficulty from ethereal solutions, and 2-hydroxy-4,8-dimethyl-5-isopropylquinoline not at all. They all formed chloroplatinates except 2-hydroxy-4,8-dimethyl-5-isopropylquinoline. The derivatives made from the latter were its benzoate, m. above 322°, and 2-chloro-4,8-dimethyl-5-isopropylquinoline, m.197°.

W. R. JOHNSON, JR., and H. W. STRALEY, III: *An Attempt to Locate the Boundaries of the Durham Triassic Basin with the Aid of a Magnetometer.*

See abstract in the Proc. N. C. Academy of Science in this issue.

### 361ST MEETING, MAY 14, 1935

A. E. RUARK: *The Wave-like Aspects of Matter.*

Slides showing interference phenomena were projected and the point was emphasized that the shape of interference patterns can be completely understood by the wave theory of light. Attention was next drawn to the photoelectric effect and other phenomena which can be largely understood in terms of a particle theory of light. The composite theory of Einstein, according to which the waves have no reality and

simply serve as guides for the particles, was discussed and severely criticised on the basis of its shortcomings. The modern view was then presented as follows. Light is an entity whose properties can only be studied with the aid of instruments (including the human eye), and the phenomena observed depend as much on the instrument as they do on the properties of light itself, assuming that this term has any meaning.

In the second part of the lecture, the experiments of Davisson and Germer, which led to the discovery of matter waves, were discussed in detail and a similar conclusion was drawn, to wit: matter is an entity which must be studied with the aid of instruments, and the results depend as much on the experimental apparatus as they do on the nature of matter itself, assuming for purposes of discussion that this term has any meaning. Thus, in most cases the particle aspect of matter is the only one coming to our attention, and refined experiments are required to reveal the wave-like aspects of matter which are all-important for atomic theory.

J. M. VALENTINE: *Sympathetic Evolution.*

The following officers were elected for the year 1935-1936:

President—C. D. Beers.

Vice-President—A. M. White.

Secretary-Treasurer—E. W. McChesney.

E. T. Browne, permanent secretary, and the editors of the Journal, W. C. Coker, H. V. Wilson, and Otto Stuhlman, continue in office.

# SYNCYTIAL STRUCTURES IN SPONGE LARVAE AND LYMPH PLASMODIA OF SEA URCHINS<sup>1</sup>

By MILDRED IRENE BOLIEK

PLATES 56-60

The two parts of this paper are based on very different experimental materials, sponge larvae and lymph plasmodia of sea urchins, but are one in that the questions considered are essentially those connected with the idea of cellular unity. The data here presented offer additional evidence that cells may exist as separate or partially connected bodies, or that their morphological individuality may be completely lost through the process of fusion, as in the case of the formation of lymph plasmodia, or the syncytial condition may precede a differentiation into cells, as in the sponge larvae.<sup>2</sup>

## PART I. SYNCYTIAL STRUCTURES IN SPONGE LARVAE

### *Material and methods*

*Lissodendoryx carolinensis* W. (George, W. C., and Wilson, H. V., 1919), a common silicious sponge of Beaufort (N. C.) harbor, provided the material for this investigation. This sponge breeds in summer, larvae being obtained during June and the first half of July. The larvae are cast out of the sponge mass into the surrounding water as free-swimming organisms. Consequently, the procedure of collecting the larvae

<sup>1</sup> A thesis submitted to the Faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Zoology.

<sup>2</sup> The experimental part of this investigation was conducted at the United States Fisheries Biological Laboratory, Beaufort, North Carolina. I am indebted to Hon. Frank T. Bell, Commissioner of Fisheries, for the privilege of working in the Laboratory, to the Director, Dr. H. F. Prytherch, and the other members of the laboratory staff for courtesies and assistance. The *Lissodendoryx* material was cultured at this laboratory, 1930, 1932, by Professor H. V. Wilson. The experimental work entailed in the second part of the investigation was made possible by a grant from the Rockefeller Fund for Research in the University of North Carolina. Sincere gratitude is expressed to the committee in charge of this fund and to Professor H. V. Wilson, under whose direction the work was pursued, for helpful suggestions and constructive criticism.

is comparatively simple. The sponge containing the embryos is removed from its place of attachment, placed in an aquarium jar or porcelain-lined bucket of sea-water and allowed to remain therein until the larvae have been discharged. Liberation of the larvae usually follows shortly after the sponge is brought into the bucket or jar. The free-swimming larvae may then be picked out with a pipette and transferred to culture dishes containing fresh sea-water. They may be kept in this way for some time if the water is changed at frequent intervals. The bottom of the culture dish may be coated with paraffin in order that the metamorphosing larvae may attach and flatten out upon a stratum which can be removed from the culture without injury to the sponge. Larvae are then picked out of the cultures at intervals and preserved. Bouin's picro-formol seems to be far superior to alcohol or to Flemming's chromo-aceto-osmic acid as a fixative for the sponge tissues. Many preparations were made from the material fixed in Flemming, but in no case did the fixation seem reliable.

#### *Histology of young free-swimming larva*

The free-swimming larva is somewhat ovoid in shape, small ( $308\mu$ - $450\mu$  long by  $150\mu$ - $250\mu$  wide), ciliated and motile. As is true of the larvae of related sponges, the surface layer, except at one pole (the posterior), is made up of a single stratum of elongated ciliated cells constituting an epithelium, the larval epithelium (Photograph 2, Pl. 56). In larvae kept in cultures the epithelium soon disappears at the non-spicular (anterior) pole in a great many larvae (Photographs 1, 3, Pl. 56; figs. 1, 4, Pl. 58). The disappearance of the epithelium at this pole marks an early step in metamorphosis, to which reference will be made later. The distal parts of the epithelial cells are rod-like, slender and separate, i.e., chinks are to be seen between the rods (Photograph 2, Pl. 56; fig. 10, Pl. 58). The zone of epithelial nuclei (nuclear zone) consists of 6-10 tiers of closely crowded, small ( $2 \times 2.5\mu$ ), elliptical and non-nucleolate nuclei (Photograph 2, Pl. 56; fig. 10, Pl. 58). In my preparations it is impossible to trace a rod to a specific nucleus in the nuclear zone (zone of epithelial nuclei) (Photograph 2, Pl. 56; fig. 10, Pl. 58). As in most larvae of this type maceration preparations are necessary to show the structure of the epithelium and the various parts of the epithelial cell. Maceration preparations have been made repeatedly by Delage (1892, Pl. XIX), Maas (1892, 1893), Wilson (1894, Pl. XVI) on related sponges. Their preparations show the epithelial cell to consist of a distal rod-like portion which extends to a specific

nucleus in the nuclear zone, the cell finally losing itself in the general interior of the sponge mass. The thickness of the entire epithelial stratum of the young swimming larva is about  $26\text{--}33\mu$ . The rod portion of this stratum measuring  $8\text{--}10\mu$ , the nuclear zone the remaining  $16\text{--}25\mu$ .

The interior of the larva has generally been described as cellular (Delage 1892; Maas 1892, 1893; Wilson 1894). In normally developing *Lissodendoryx* larvae, and Wilson (1935) has shown that the same condition exists in *Mycale lorenzi*, the interior of the larva consists of a non-cellular, granular-reticular cytoplasm in which are imbedded two kinds of nuclei (to be described below)—a syncytium (Photographs 1, 2, 3, 4, Pl. 56; figs. 1, 2, 5, 10, Pl. 58). The nuclei are scattered in the cytoplasm and we pass directly from one nucleus to another without encountering any cell boundaries. Here and there small accumulations of fluid may interrupt the continuity of the syncytium as is shown in Photographs 2, 3, Pl. 56, but the true syncytial nature of the interior cannot be doubted if thin ( $3\text{--}5\mu$ ) sections of the larva be studied with the oil immersion and preferably a high (12–15K) compensating ocular. In *Lissodendoryx* there is no anterior watery mass of collenchyma (cavity of some writers) as is present in some sponges of this group (*Mycale*, *Spongilla*) (See Photograph 1, Pl. 56). The syncytium is uniformly dense throughout, save where interrupted by the fluid spaces (Photographs 2, 3, Pl. 56).

In one end of the larva, the end which is posterior in movement, there is present a great bundle of megascleres, long tylotes ( $140\mu$  or longer) (Photograph 1, Pl. 56; fig. 26a, Pl. 59). This end of the larva is known as the spicular pole. Microscleres, sigmata (figs. 26b, d) and isochelae (fig. 26c), the small spicules of the interior, are found in the region of the spicular pole and here and there elsewhere in the interior.

At the end of the larva designated as the spicular pole, ciliated epithelium is lacking. The surface layer at this pole consists of a single layer of non-nucleolate epidermal cells which in some larvae are scarcely distinguishable, if at all, from the general syncytium of the interior. In *Lissodendoryx* larvae not yet liberated from the parent tissues, these epidermal cells are distinct and elongate, columnar, (fig. 3, Pl. 58); in free-swimming larvae these cells, where distinctly marked out, are flat and fusiform, as seen in longitudinal sections of the larva (right of fig. 2, Pl. 58). The transition from epithelium to epidermis is usually very abrupt (figs. 2, 3, Pl. 58).

As said above, the syncytium embraces two kinds of nuclei: nucleolate and non-nucleolate (fig. 1, Pl. 58). The nucleolate nuclei are some-

what larger ( $4.4\mu$ ) than the non-nucleolate ( $3.3\mu$ ) nuclei. Both are roughly spheroidal structures. There is no definite grouping or massing of the two kinds of nuclei in any of the larvae, but in general the nucleolate nuclei are not present in the immediate vicinity of the epithelium (figs. 5, 10, Pl. 58) nor at the spicular pole (fig. 2, Pl. 58), but are in the majority in the central portion of the larva.

#### *Normal metamorphosis of the free-swimming larva*

As already stated (p. 253), metamorphosis begins quite early at the non-spicular (anterior) pole in a number of apparently normal free-swimming larvae (Photographs 1, 3, 4, Pl. 56; figs. 4, 5, Pl. 58). In these larvae, at the designated pole, the nuclear zone of the larval epithelium thins out conspicuously (Photograph 4, Pl. 56; fig. 5, Pl. 58). In this process some of the nuclei reach the surface and are lost (fig. 4, Pl. 58); others wander into the interior where many of them die or degenerate. The thinning out process may go so far as to leave only a single layer of epithelial nuclei at this pole, these nuclei lying quite at the surface (figs. 1, 4, Pl. 58; Photograph 3, Pl. 56). Figure 5, Pl. 58, shows an earlier stage in the thinning out process: several rows of epithelial nuclei still exist in this region and pass gradually into the thicker lateral zone of nuclei (at the right of the figure).

The free-swimming phase in the development of normal larvae is, in time, a relatively short period. The larvae rapidly transform from ovoid, ciliated and motile organisms to thin, flattened and attached organisms whose expanse is 6–10 times its depth (thickness) (fig. 8a, Pl. 58). Such a transformation may come about in the course of twenty-four hours. Internal changes associated with the change in form are discussed below.

*Metamorphosis of the epithelium.* Flattened sponges which were picked out of the cultures at the end of twenty-four hours, fixed and sectioned show, first of all, that the epithelial stratum characteristic of the free-swimming forms has disappeared from the surface. The disappearance of the epithelium is complete over the entire surface, i.e., no remnants of it remain (Photograph 5, Pl. 56; fig. 6, Pl. 58). The epithelial nuclei, formerly a part of the epithelial stratum, are found scattered through the interior (figs. 6, 8b, Pl. 58, representing parts of vertical sections through such sponges). The distal parts, from nucleus outwards, of the epithelial cells have completely disappeared as such—retarded larvae described below (p. 259) show them to metamorphose *in situ*, fusing with one another and the general syncytium of

the interior. The epithelial nuclei have evidently wandered into the sponge interior probably bringing some surrounding cytoplasm with them, but not in the form of cells, i.e., not as the original epithelial cells.

*Formation of epidermis.* There is as yet no well defined layer of cells at the surface of the flattened sponge mass (figs. 6, 8a, 8b, Pl. 58). The line which marks the surface is in most places simply the outermost layer of the syncytium (Photograph 5, Pl. 56; figs. 6, 7, 8b, 9, Pl. 58) or the limiting membrane. We might say, however, that an epidermis is forming since we find an occasional flattened epidermal (non-nucleolate) nucleus at the surface and even a well outlined flattened cell or two (fig. 6, Pl. 58), together with many rounded non-nucleolate nuclei imbedded in the syncytium a short distance below the surface (figs. 6, 8b, Pl. 58). Doubtless, these non-nucleolate (epidermal) nuclei will move to the surface and cell bodies will form round them.

*Breaking up of syncytial interior into cells.* The interior of a flattened larva such as is shown in photograph 5, pl. 56, and fig. 6, pl. 58, is still syncytial, i.e., we encounter no cell boundaries. In general, the syncytium is compact and continuous (Photograph 5, Pl. 56; fig. 6, Pl. 58), but there are places, in some of the twenty-four hour larvae, where watery accumulations so separate the cytoplasm into tracts as to give the appearance of vaguely outlined cells—cells with no distinct limits and as yet very much interconnected. Such places occur most frequently in the extreme periphery of the flattened mass (fig. 7, Pl. 58). This early breaking up of the cytoplasm into dense and watery tracts is, as we shall see, a preliminary step in cell differentiation.

Indeed, we find, in these flattened masses from the twenty-four hour cultures, not one but several stages in the differentiation of cells: 1) the compact, continuous syncytium with few or no watery accumulations (fig. 6, Pl. 58); 2) larvae in which watery accumulations are beginning to appear in some abundance, especially in the peripheral region (fig. 7, Pl. 58); and finally, 3) larvae which are very generally interrupted by watery spaces which mark out, more or less vaguely, cells or cell-like structures (fig. 9, Pl. 58), but the cells, although indicated, lack sharp, distinct boundaries and are, as yet, very much interconnected.

The syncytium in these last mentioned larvae is broken up by watery accumulations and by canal spaces as well (see figs. 9, 11, 12, Pl. 58). Figure 11 is indicative of the extent to which the mass is traversed by canal spaces. The canal spaces are in part simply bounded by the general syncytium, and in part imperfectly lined by non-nucleolate cells (figs. 9, 12, Pl. 58).

The nuclei found within the more or less vaguely outlined cells of these larvae are the same nucleolate and non-nucleolate types seen in preparations of the free-swimming stage. Both kinds of nuclei appear normal (healthy). Many of the epithelial nuclei, on the other hand, in the more advanced larvae are degenerate or dying and their total number is much less than one would expect if they are to participate in chamber formation. There is as yet, in the most advanced of my larvae, no grouping of epithelial nuclei to form chamber primordia.

Some of the larvae exist as rounded (ball-like), massive and still loosely attached bodies at the end of two or three days in the cultures. Sections show that they have scarcely departed from the normal course of development except that they have been slow to attach and flatten. The metamorphosis of the epithelium has proceeded as in the type, that is the rods, except here and there in one case, have disappeared and the surface layer of the larva, like the interior, is made up of a granular-reticular syncytium; the nuclear zone of epithelial nuclei has broken up, the nuclei themselves lying for the most part scattered at some distance from the surface and through the interior. In some places, however, these nuclei have approached and lie at the surface, possibly a preparatory step toward their discharge from the larva. A number of the epithelial nuclei appear abnormal but there are some good ones in the interior and still more nearer the surface. The body of the larva is syncytial. In its more superficial layer lie non-nucleolate nuclei in relatively large number. This may be regarded as a step toward the formation of the epidermis.

Quite a large number of the expanded and firmly attached larvae which were picked out of the cultures 2-3 days after their liberation as free-swimming larvae, have made little or no progress in cell differentiation and the formation of canal spaces. A particularly noticeable feature in them is the great number of degenerate epithelial nuclei in the cytoplasm (fig. 8b, Pl. 58). (Contrast in respect to this point fig. 8b with figs. 7, 9.) It could hardly be said that these particular larvae are atypical. It is rather that they are slow to undergo the changes leading to cell differentiation, and canal formation. It is quite possible that they will undergo complete metamorphosis in time.

*Summary of normal metamorphosis.* The metamorphosing process, in so far as it had proceeded in the larvae described, involved the following changes: (1) the attachment and flattening out of the larva; (2) the disappearance of the epithelial stratum, as such, from the surface of the sponge mass; (3) the migration of the epithelial nuclei from the region of the nuclear zone: some to the surface where they are thrown

out of the body, others into the interior of the body; (4) the metamorphosis of the rod portion of the epithelial cell *in situ*; (5) the formation, in places, of an epidermis; (6) the breaking up of the compact, continuous syncytium of the larva by watery tracts into areas which resemble cells, and indeed are cells in an early stage of differentiation. The developmental stages preserved do not proceed beyond this point.

*Larvae retarded in metamorphosis and showing atypical features*

In cultures which are kept from day to day, a number of the larvae fail to attach and flatten out; others attach and flatten, but are slow to undergo the changes associated with the flattening process. These retarded larvae present some phenomena of considerable interest.

*Retarded larvae still free.* The first group to be considered consists of free, short and thick larvae (fig. 13, Pl. 59), with an epidermal area larger than in larvae which have been recently discharged from the parent. Typical individuals measure  $266.5\mu \times 233\mu$ ,  $291.5\mu \times 225\mu$ . Larvae of this kind were obtained in the cultures after 2, 3 and even 7 days. They have been figured by Wilson (1894, Pl. XVI) who thought they represented a normal, i.e., constant phase in the development. In them although unattached, the formation of the epidermis has progressed to some extent from the spicular pole forwards. Parts of longitudinal sections through such larvae are shown in photographs 6, 7, Pl. 57, and figs. 14, 15, Pl. 59.

These larvae differ from the type described as normal in that the uniform syncytium of the latter is partially broken up in the former into large and distinctly outlined cells. These cells are found especially in the vicinity of the megascleres. In the neighborhood of such an area the syncytium may be much as it was before, and the contrast between the two kinds of tissue is sharp (fig. 14, Pl. 59). This figure shows that the extreme spicular pole (right part of figure, with a distinct covering layer of epidermal cells) is dense and unbroken into cells. In it lie many non-nucleolate nuclei. In the region of the non-spicular pole the syncytium is much less dense, being more vacuolar, i.e., full of small vacuole-like spaces (Photograph 7, Pl. 57). Metamorphosis has just begun at this pole, as photograph 7 would indicate, and epithelial nuclei are moving out of the zone in which they have been aggregated: some to the surface where they are extruded (see photograph 7, Pl. 57), others into the interior.

The cells found in these larvae in the vicinity of the megascleres are large, for the most part with distinct ectoplasmic membranes and in the

main spaced well apart (Photograph 6, Pl. 57; fig. 15, Pl. 59). They are rounded or irregularly polygonal as seen in section. Their nuclei appear normal and the cytoplasm has undergone no marked change from that of the former general syncytium or remnant of the same. The great majority are nucleolate. Some of the cells or cell-like masses contain two nuclei.

These larvae do not appear to be degenerate or undergoing a slow process of death—the cytoplasm and nuclei appear normal enough, and yet the early breaking up of the syncytium before transformation of the epithelium may be a step toward degeneration, or possibly, it represents the precocious beginning of a process (breaking up of syncytium into cells) which normally occurs only after the sponge has attached and flattened out, and the epithelium has disappeared, as such, from the surface of the mass. The independence of the cells speaks for the former view.

*Retarded larvae, loosely attached, still with larval shape.* Some larvae were loosely attached even seven days after liberation as free-swimming forms. They had retained the larval shape, that of a short thick larva which had attached along one side. In these short, thick forms much of the epithelium has disappeared from the surface. It persists in general, at one end, that end which represents the non-spicular pole (left parts of figs. 16, 17, Pl. 59). And in some cases, small patches or areas of the epithelium had been retained on the upper surface as opposed to the surface of attachment. Between these patches, and over the surface where there is no epithelial stratum, an epidermis is forming.

The scattered remnants of the surface epithelium (found in these short, thick larvae that have been delayed in metamorphosis) show a peculiar abnormality. What we see is a surface stratum of thick blunt structures (figs. 16, 17, Pl. 59) which occupy the position of the outer parts of the rods of an earlier stage. They measure about  $4.5\mu$  in thickness and so are much thicker than the original rods. Their location, arrangement and shape show that they represent the outer ends of the original rods. The pictures indicate (compare figs. 16, 17 with fig. 14 of Pl. 59) plainly that the epithelial cells have fused with one another *in situ* except at their outer ends, the fusion having thus progressed from the interior toward the surface of the larva. Possibly the outer ends of several rods fuse to form one of the thick blunt structures, and this seems quite probable. Whereas in figure 16, pl. 59, the epithelial nuclei are no longer found massed in a zone near to the surface but are scattered in the interior, in figure 17, pl. 59, the zone of epithelial nuclei

is still recognizable and the rod structure may be here and there traced as striated material to some distance from the surface. Plainly the section (embryo) shown in figure 17 represents a stage in the metamorphosis of the epithelium earlier than that shown in figure 16.

The retention at the surface of these larvae of the thickened outer ends of the epithelium cells, while the inner cell bodies have disappeared as such, is a peculiar phenomenon which seems not to have been observed before. It is probably then to be classed, as is here done, as an abnormality, a departure from the usual course of events. The departure, however, cannot be a great one and it serves to bring out distinctly the fact that the epithelial cells do not migrate into the interior but instead, fuse with one another *in situ*.

In these larvae, the formation of epidermis goes on as in the more typical ones. In both, as the epithelial nuclei retreat from the surface, the non-nucleolate nuclei of the interior approach the surface (figs. 6, 7, Pl. 58, for the normal, figs. 16, 17, Pl. 59, for the abnormal). The non-nucleolate nuclei of the atypical larvae appear to be quite normal. They exhibit no swelling or shrinking and the chromatin is scattered in the karyolymph, not aggregated into a lump, nor condensed against the nuclear membrane. In the areas where the rods as such have quite disappeared, the non-nucleolate nuclei lie quite close to the surface, are for the most part somewhat flattened, and around them more or less flattened cell bodies are in some degree differentiated out of the general syncytium (figures just referred to). The actual emergence of epidermal cells on the surface of the larva is recorded by many observers (Goette 1886, Delage 1892, Maas 1892, 1893, Evans 1899, Wilson 1935). With the exception of Wilson they think of this as the sole process which leads to the formation of the definitive epidermis. Wilson thinks of it as only one method, finding that the method here described occurs also in his larvae (*Mycale*). In this research special attention was not concentrated on the question. Possibly the mass shown in fig. 17, pl. 59, surrounded by remnants of the rods, is an epidermal cell about to emerge at the surface.

The breaking up of the syncytium into independent cells noted above has progressed in these larvae to a varying extent. In some (fig. 16, Pl. 59) most of the interior still consists of a continuous, granular-reticular cytoplasm in which are scattered the three kinds of nuclei; but, in the central region, there are some, not a great many, well-defined cells and many more cells not so well defined (not shown in figure referred to). In other larvae (fig. 17, Pl. 59) while the interior is still in

part syncytial, a considerable part of the syncytium has broken up into cells, or cell-like masses often quite large which contain two, three or four nuclei. These masses may be distinctly or vaguely defined, and may hold within them a great many epithelial nuclei—all of them pycnotic (fig. 17, Pl. 59). Most of the mesenchymal nuclei within these cells and irregular cell-like masses are nucleolate, but some are non-nucleolate. Such nuclei are normal, and no evidence of degenerative change is to be observed in them. In these short, thick larvae that part of the body which represents the spicular pole consists of a dense, compact mass of cytoplasm, not yet broken up into cells and containing a great many non-nucleolate nuclei (similar to fig. 14, Pl. 59, of a retarded free-swimming larva).

*Retarded larvae that have attached and flattened.* Other larvae which had been kept in cultures for seven days were attached and considerably flattened, and yet showed in places remnants of the larval epithelium (Photograph 9, Pl. 57; fig. 18 1 ep, Pl. 59). Between such patches of epithelium we find an epidermis the cells of which are fairly distinct (fig. 18 ep, Pl. 59). The remnants of epithelium present much the same appearance as in the retarded larvae, just discussed, in which the body was still thick and short. That is we see at the surface thick blunt remnants of the outer ends of the rods, immediately below which there is continuous cytoplasm. Here and there (to the left, in fig. 18) these can be traced into striated material lying deeper, which obviously represents the inner parts of the rods. In the case of some of the remnants of the larval epithelium we find a condition about like that shown in figure 17, Pl. 59. That is, below the superficial remnants of the rods there are still present many epithelial nuclei, representing the earlier compact zone which has now begun to break up. In the case of other such areas there are (fig. 18, Pl. 59) almost no epithelial nuclei in the superficial region of the larva. Evidently they have migrated into the interior. In the parts of these larvae showing remnants of the larval epithelium the initial step in the formation of the epidermis had taken place. That is, epidermal non-nucleolate mesenchymal nuclei had accumulated in considerable number close to the surface (fig. 18, Pl. 59). In the regions where the metamorphosis of the epithelium is complete an epidermis of non-nucleolate cells has taken form (fig. 18, ep, Pl. 59). It is pretty well defined over the entire surface of attachment (Photograph 9, Pl. 57).

The breaking up of the syncytium into cells has progressed and there are now a great many of such cells (Photograph 9, Pl. 58; fig. 18, Pl. 59).

They are for the most part nucleolate but some are non-nucleolate. The nuclei, both nucleolate and non-nucleolate, appear quite normal. Many of the cells contain epithelial nuclei in addition to their own and in some cases the epithelial nuclei are all pycnotic, evidently dead or dying.

*Summary on the breaking up of the syncytium into cells in the retarded larvae.* The facts shown in figures 16, 17, 18, Pl. 59, fall into a series showing a progressive breaking up in the retarded larvae of the original syncytium into cells that have for the most part distinct ectoplasmic membranes and are independent. The more advanced stages in this process (fig. 18, Pl. 59) are conspicuously different from the earlier syncytial stage and significantly different from the normal phase of metamorphosis described for related sponges in which the cells are in general united by strand-like inter-cellular connectives (Delage 1892, Pl. XVII; Wilson 1894, Pl. XVII). The process would seem in fact to be an abnormal step which in the end will probably lead to the death of the metamorphosing larva. The difference in structure between such larvae and more normal ones is brought out on comparing fig. 18, Pl. 59, with such sections as that shown in figure 9, Pl. 58, in which the normal cell structure is beginning to appear along with the formation of canals. The latter it will be noted have not begun to form in the atypical specimens (figs. 16, 17, 18, Pl. 59) under discussion. This abnormal breaking up of the interior into independent cells is, I take it, to be looked on as representing an early phase in a reaction of sponge larvae to unfavorable elements in the environment, a reaction which under circumstances may go much farther, as is indicated in photographs 8, 10, 11, Pl. 57, and which will be discussed later.

#### *Oedematous unattached larvae*

A small group of unattached larvae is referred to under this heading. Fluid has accumulated within these larvae filling large irregular inter-connecting spaces (Photograph 11, Pl. 57), between which lies what remains of the once syncytial interior, now broken up into rounded cells with distinct outlines. These larvae were preserved two days after their liberation from parent tissues. They vary somewhat in size, but there is no great deviation from normal dimensions as the following figure would indicate:  $383\mu \times 166.6\mu$ ;  $400\mu \times 183\mu$ ;  $375\mu \times 325\mu$ . The cells of the interior form irregular, often interconnecting groups. They are spheroidal and have very distinct ectoplasmic membranes (Photograph 11, Pl. 57; fig. 22, Pl. 59). It would seem that the cells separate out of the general syncytium first along the surfaces bounding the fluid

spaces, cell formation then proceeding toward the interior of the particular syncytial mass until it is wholly or nearly broken up into cells as in photograph 11, Pl. 57, figs. 19, 20, 21, 22, 23, Pl. 59. Thus in figure 19, Pl. 59, which represents the anterior part of a longitudinal section through one of these larvae, the part of the section is bounded above (actually toward the interior of the larva) by a large irregular fluid filled space. The syncytial material bordering upon this space is evidently just beginning to break up into the spheroidal cells under discussion. Two are shown in the figure. The same fact is shown in figure 21, Pl. 59, representing the anterior end of a longitudinal section through a similar larva, in which the syncytial material immediately adjoining the fluid filled space (ffs) is obviously breaking up into cells.

Small remnants of the original syncytium remain here and there, but the greater portion of the interior is broken up into the spheroidal cells which are more or less of a size, some nucleolate and some non-nucleolate. The cytoplasm about the nuclei while granular is not so dense as the syncytial cytoplasm of the normal larva. The nuclei themselves are more or less pycnotic (fig. 22, Pl. 59), the chromatin often condensed and lying against the nuclear membrane in the form of thickenings or granules (fig. 23, Pl. 59), the inner portion of the nucleus being empty.

As is shown in photograph 11, Pl. 57, and figure 21, Pl. 59, the fluid filled spaces almost isolate a relatively thin superficial layer from the interior. This layer represents the original larval epithelium together with some of the adjoining syncytial interior. In one of the larvae patches of rods and remnants of rods are found at the surface, but elsewhere in this larva and in the other larvae the rod-like epithelial cells have disappeared as such. In some of the larvae, metamorphosis of the epithelium in certain regions apparently occurred more or less in the usual way, leaving (figs. 20, 21, Pl. 59, representing parts of longitudinal sections) a peripheral stratum of syncytial cytoplasm containing many epithelial nuclei together with some non-nucleolate mesenchymal nuclei. At the outer surface of this stratum it is clear in some cases that the syncytium is breaking up into small cells (figs. 20, 21, Pl. 59) the nuclei of which are epithelial nuclei. These are being budded off to the exterior. It is possible, perhaps probable, that the closely set projections found at the surface in places (fig. 21, Pl. 59), and into some of which epithelial nuclei are travelling, represent not new formations but the outermost remnants of rods which further inwards have fused together.

But the peripheral layer of these larvae presents in most places, as

seen in sections vertical to the surface, the appearance shown in photograph 11, Pl. 57. Here we see epithelial nuclei present in great numbers, passing out at the surface inside small rounded cells. Further in the picture is not so clear. The nuclei are possibly interconnected by syncytial cytoplasm as in figures 20, 21, Pl. 59. Or here too, they, or some of them, possibly lie in small cell bodies like those at the surface.

In general there has been no migration of the epithelial nuclei into the interior of the larvae. Only a very few of them appear there, occasionally one or two within one of the spheroidal cells of the interior. They have remained in the peripheral stratum of the larva and many, as said, are passing out at the surface into the surrounding water, not as nuclei (compare fig. 4, Pl. 58) but within cell bodies.

Pictures such as that reproduced in photograph 11, Pl. 57, leave it uncertain how far the metamorphosis, fusion *in situ* of the epithelial cells, had progressed or even whether it had started, before the abstraction of the small cells with their contained epithelial nuclei began. Possibly unlike what is shown to be going on in places represented by figures 20, 21, the long slender epithelial cells may break up directly into small nucleated portions and cytoplasmic scraps.

The tendency in these larvae to break up into independent, dissociated cells is also seen in some of them at the spicular pole (fig. 19, Pl. 59). In these cases the surface layer of the larva is budding off rounded cells, and also cell-like masses of cytoplasm in which no nucleus is apparent. The nuclei appearing in these cells and indeed in all the cells budded off at the surface in these larvae are pyenotic: i.e., the nucleus is either represented by remnants of chromatin or the chromatin is condensed against the nuclear membrane leaving the center of the nucleus clear.

*Summary.* These larvae are obviously abnormal and in a pathological state. How long they might have lived is a question, but it seems clear that they would never have been able to undergo metamorphosis. The salient feature which they exhibit is an intensification of that noted in retarded larvae, i.e., nuclei surround themselves with individually independent cytoplasmic bodies having distinct ectoplasmic membranes. But whereas in the retarded larvae this process affected only a part of the interior, in the oedematous larvae the exterior as well as the interior is involved. The whole body is breaking up into cells which with their spheroidal shape and ectoplasmic membranes agree with our general idea of the protoplasmic state best suited to withstand an injurious environment from which for the moment escape through locomotion is impossible.

The tendency to break up into independent cells is strikingly shown in sponges undergoing "reduction" in standing water or in sea water made chemically different from the normal (Metschnikoff 1879, Maas 1906, Müller 1911, Wilson 1907). In a reducing sponge while many of the cells die in the dissociative, "sauve qui peut," reaction, some come together in spots where the environment is probably more favorable than elsewhere, and passing into a new coöperative phase succeed in establishing a regenerative body (Laurent 1844, Lieberkühn 1859, Maas 1906, Müller 1911, Wilson 1907). In the lack of a better explanation, the idea may be provisionally entertained that the sponge larvae here described, are undergoing an analogous process, in response to stimuli which induce a breaking up of the whole into small independent nucleated masses, a breaking up which is adaptive in so far at least that the life of such masses is for a time prolonged and thus allowance made for the undoubtedly rare chance that they may come together again, like the cells of the reduction body, under better circumstances and establish some kind of a regenerative mass.

In the actual larvae of this investigation such regeneration would seem to be impossible since the larvae have already become pathological but could the cells shortly after their formation be separated from one another and then brought together under good conditions a regenerative body might at least conceivably be formed. This line of thinking is admittedly speculative but the breaking up of the larva into cells is a sufficiently striking phenomenon to call for speculation as to its meaning. To dispose of it as a mere mortuary phenomenon is not possible, for the question would still remain, why should not the larval body die bit by bit as it is, the protoplasm disintegrating into the surrounding water or internal fluid, instead of, first, so changing its morphological structure?

#### *Larvae invaded by bacteria*

In some of the cultures a number of attached larvae were invaded by bacteria and partially destroyed. The basal region of the sponge is most commonly affected, although the invasion may extend over most of the sponge surface. The bacteria collect about the base or the sides of the sponge, and in time gain entrance into the sponge mass. The surface layer is destroyed in the region of the infection, and thus the interior of the mass is exposed (Photographs 8, 10, Pl. 57). Much of what was the body is now occupied by fluid with abundant bacteria. The general syncytium has disappeared and cytoplasm has condensed around mesenchyme nuclei thus forming cells with very distinct ectoplasmic mem-

branes (Photograph 10, Pl. 57; fig. 24, Pl. 59). Such cells usually contain a number of degenerate epithelial nuclei (Photograph 8, Pl. 57), and we often get cells within cells (fig. 24, Pl. 59, those marked b) or cells within outer non-nucleated layers of cytoplasm. Such appearances indicate the occurrence of a form of localized digestion akin to phagocytosis. What happens seems to be this. A mesenchymal nucleus, presumably sick, along with the immediately surrounding cytoplasm is isolated from the general syncytium as a spheroidal cell in a vacuole. This we would regard as a quarantine measure taken for the protection of the larva in general. (In following out the idea of adaptive responses of protoplasm it is difficult to avoid the use of language which in itself might imply the existence of a conscious purpose in the protoplasmic mass. No such meaning is, of course, intended.) The next step would be the digestion of the isolated cell. Since this proceeds gradually, such cells are met with in several phases, varying from a normal appearance as in b at the upper right of figure 24 to the condition of b at the bottom of figure 24. The latter cell does not quite fill its vacuole and its nucleus has disintegrated. It was presumably quite dead when the larva was fixed. Now as the effect of the bacteria is increasingly felt the syncytium in general breaks up into independent cells, for the most part spheroidal, but immediately round a vacuole, with its included degenerate cell, only a layer surrounding the vacuole like a shell is cut out of the syncytium. This is sometimes nucleated and so we get the appearance shown in b at the bottom of figure 24, Pl. 59. But again no nucleus is to be seen in this outer layer, as in the case of several of the masses of figure 24. Some of the masses, as for instance the largest in figure 24, have a stratified appearance as if concentric layers of cytoplasm, one after the other, had been cut out of the syncytium. In most cases the original vacuole has disappeared and we simply see cell within cell, or cell within outer cytoplasmic layer. Where the bacterial invasion has destroyed the surface layer of the sponge the free rounded cells of the interior wander or are washed out of the sponge body into the surrounding water. Some of the larvae were caught and fixed at a time when this process was obviously going on. Eventually all the rounded cells or other masses must be disseminated. As already said, in the space between the rounded cells or other masses of the interior (Photograph 10; fig. 24) we find fluid with abundant bacteria. In the fluid there are also present cell fragments, remnants of nuclei, and occasional cells of obviously degenerate character (fig. 24, Pl. 59, at bottom left and right).

What has been said (pp. 264 and 265) as to the meaning of the

mortuary changes in the oedematous larvae applies with equal force to these larvae suffering in a very plain way from bacterial invasion. In both and in the retarded larvae as well, the obvious fact is that the sponge body breaks up, more or less completely, into independent cells, these eventually rounding up with conspicuous ectoplasmic membranes. And in seeking for some explanation of this behavior we seem to be driven to make use of the idea that protoplasmic behavior in general is at bottom adaptive and that sponge larvae, under conditions which make the usual life-cycle impossible, may exhibit a very simple form of this fundamental tendency.

#### PART II. SYNCYTIAL STRUCTURES PRODUCED BY LYMPHOCYTES OF SEA URCHINS

The cells (corpuscles) which float in the perivisceral fluid of Echinoderms have occasioned comment since the writings of Valentin (1842) and Williams (1856). The different kinds of corpuscles found herein were first described and figured by Geddes (1880), and soon after by Cuénot (1891). Since the work of Geddes many investigators have come to study the corpusculate fluid of the Echinoderms and other invertebrates.

##### *Cellular elements floating in the perivisceral fluid*

Geddes (1880) describes and figures for a regular sea urchin, *Echinus sphaera* or *Toxopneustes lividus* five kinds of cells. Cuénot (1891:614) recognizes the same cells and groups them as amoebocytes and vibratile corpuscles. I find in this study of the cellular elements contained in the perivisceral fluid of *Lytechinus variegatus* five distinct kinds of cells which undoubtedly correspond to those described by Geddes, Cuénot, Kindred and other investigators. (1) The most striking cell element (corpuscle) in the freshly extracted fluid is the amoebocyte with red inclusions (spherules of Kindred), first discovered by Erdl (1846) and described by all subsequent authors. These cells are more or less spherical structures, measuring 12–13 $\mu$  across, with clear ectoplasmic membrane, and closely crowded, rounded spherules which obscure the nucleus (fig. 1, Pl 60). (2) Another conspicuous element in the perivisceral fluid of *Lytechinus variegatus* is the amoebocyte with colorless, refringent spherules (fig. 2, Pl. 60). This cell presents the same appearance as to size and shape as does the pigmented cell; the size of its spherules, however, slightly exceeds those of the red cells. (3) Another type of amoebocyte resembling the first two, save for its size and the

color of its spherules, is less abundant than either the red or the colorless cell. These are the yellow-green amoebocytes, about  $6\mu$  in diameter (fig. 3, Pl. 60). Most investigators believe that the yellow-green cell is but a phase of the red amoebocyte (See Geddes, Cuénot, Kindred, etc.).

(4) The fourth kind of amoebocyte found in the perivisceral fluid of *Lytechinus* is the leucocyte, a term first used by Goodrich (1919) and later by Kindred (1921, 1924) for this kind of cell. The leucocyte as it appears *in vivo*, or immediately upon its extraction shows a nucleus ( $6-8\mu$ ) surrounded by a relatively narrow zone of granular cytoplasm, bounded peripherally by a varying number of non-granular flaps, only the edges of which are visible with ordinary lighting (fig. 4, Pl. 60). The flaps do not lie in one plane, but go out from any part of the cell. This corpuscle was known to Geddes (1880), who observed it in *Echinus sphaera* and *Toxopneustes lividus*, but he describes it as having long, filiform and ramified pseudopodia. Cuénot (1891) too, describes the leucocyte as having very long and very numerous pseudopodia. Goodrich (1919) discovered that the real structures round the central cell body are membranous lobes passing out from the cell in different planes; and that Geddes' long filiform and ramified pseudopodia were probably only optical sections of such lobes. Kindred confirms Goodrich and speaks of these lobes as membranous flaps. Fauré-Fremiét (1927) describes the flaps as vesicular or bubble-like expansions of hyaloplasm, the contents not especially referred to. Lison (1930) regarded the flaps as vesicular, the wall made up of ectoplasm, the contents a perfectly hyaline fluid. The surface layer of the flaps in question is certainly ectoplasmic. As to the question whether they are vesicular with fluid contents, I may say that in the living preparations they certainly do not appear to be vesicular. However, while studying the living corpuscles no special attention was paid to this point, and my preparations of fixed material, as one would expect, do not permit a decision. As to the structure in general of these corpuscles, it may be added that the earlier observers who described them as provided with long, filiform pseudopodia (Geddes, Cuénot), may have been looking not at the natural phase of the corpuscle as it exists in the coelomic cavity, but at a later phase which is discussed below.

(5) The fifth and last kind of cell found in the perivisceral fluid, the vibratile corpuscle or flagellate cell, is very numerous and very active. The cell body measures  $8\mu$  in diameter, and its flagellum is four times as long ( $32\mu$ ). The cell body contains a small nucleus, and the sur-

rounding cytoplasm includes a number of granules or condensations of some sort. The flagellum, usually figured and described as thread or whip-like (fig. 5, Pl. 60), is in reality a thin, blade-like structure wider than the cell body and tapering distally (fig. 5', Pl. 60). As this flagellum beats to and fro, it has the appearance of a line or thread, but if viewed with the dark field, every cell is seen to be provided with a blade-like process (figs. 5, 5', Pl. 60). Geddes, Cuénot, Kindred, all described the vibratile corpuscle. The flattened blade-like flagellum has not previously been recorded.

#### *Behavior of corpuscles in vitro*

The behavior of the corpuscles which float in the coelomic (perivisceral) cavity may be studied microscopically *in vitro*. The test of the urchin is punctured, the perivisceral fluid is drawn up into a parafined pipette and then quickly transferred to a slide, previously cleaned and the drop immediately covered. The hanging drop method may be used, but observations are more easily made on the former type of preparation.

The amoebocytes with the red, colorless, and yellow-green spherules (inclusions) undergo a change in form very soon after extraction. The ectoplasmic cell boundary, at some point on the cell surface, gives place to a "bleb-like" protrusion of the cytoplasm, and several such in rapid succession until the entire cell boundary, formerly so distinct as a sharp line, is now lost in low pseudopodial outgrowths which are in constant "play," i.e., changing (figs. 6a, b, c, Pl. 60). The spherules begin to move about within the cell, and soon (1-2 minutes) one of the "blebs" flows out as a longer pseudopodium (fig. 6d, Pl. 60), the spherules following. Thus we get actively amoeboid cells, in general distinctly elongated, in some cases measuring 35-48 $\mu$  in length (fig. 7, Pl. 60). The nucleus of the living cell now appears as a clear space among the spherules. These amoeboid cells slip and slide over each other without any resulting fusion or coherence. They may, however, become entangled among or captured by the leucocytes (figs. 8a, 8b, Pl. 60). The cell with spherules, in its attempts to pull away from its captor, undergoes various modifications in form: flattens, elongates, becomes almost spherical, etc., while the transforming leucocyte is apparently sticky. No visible fusion occurs between these two kinds of cells, and the cell with spherules may escape its captor. Fixed preparations likewise show amoebocytes with spherules adhering to, or held by, single leucocytes or aggregates of them, but no definitely clear

instances of fusion between the cells with spherules and leucocytes, or between cells with spherules and vibratile corpuscles have been found.

As said, page 267, all the amoebocytes with spherules in a fresh drop of fluid show a more or less spheroidal shape. And in a drop which is fixed on the slide immediately upon extraction this same shape is observable for all the cells with spherules. This would suggest, at least, that the amoebocytes containing spherules exist as spheroidal structures in the coelom of the normal animal, although it is of course possible that the spheroidal shape is the result of shock and that the cells in the coelom are normally amoeboid. This seems improbable since the cells, if the drop be examined immediately, are all spheroidal. In "drop preparations" fixed 10 to 30 minutes after the fluid was extracted the cells with spherules are elongate, i.e., fixed in the amoeboid condition. Some may measure 35-48 $\mu$  in length (fig. 7, Pl. 60). Many of these cells show beginning pseudopods. The pseudopod at this phase is entirely ectoplasmic, elongated and of considerable size (fig. 7, Pl. 60).

The leucocyte (amoebocyte with membranous flaps), however stable it may be *in vivo*, is very unstable *in vitro*. The membranous flaps constantly undergo changes in form: They may be produced into long processes (fig. 9c, Pl. 60), or may disappear as others enlarge and new ones take form. Very quickly, that is, within a few seconds to minutes, the leucocyte takes on another habitus. Upon reaching the surface of the slide it flattens out into a thin expansion (lamina), the whole body extended in one plane (fig. 11, Pl. 60). The nucleus of such a cell stands out as an ellipsoidal body surrounded by finely granular cytoplasm. That the leucocyte is very unstable *in vitro* the several investigators agree. Hjalmar Theél (1919-1921) describes two very dissimilar types of amoebocytes found in the perivisceral fluid of Echinoderms. These he regards as distinct in themselves and calls them "bladder-amoebocytes" and "hyalin-plasma amoebocytes." But Kindred (1924) raises the question of two possible functional states of the same cell. Fauré-Fremiét (1927) pursues the question further, and describes the leucocyte in the coelomic cavity as in the passive phase. And that designation is here adopted. Fauré-Fremiét (1927) emphasizes the immediate transformation of the passive leucocyte into the active or flattened, expanded form (his "choanoleucocyte"—a term adopted from A. Dehorne (1925)).

Leucocytes come together and cohere in the passive phase (figs. 10a, 10b, Pl. 60), or in phases transitional between the passive and active condition to form aggregates of various sizes. This observation has also been made by Kindred (1924) and Lison (1930).

The flattened, laminate cells may, and often do, fuse to form bi-, tri-, and multi-nucleate masses, even extensive membranes or sheets. However, the dark field is necessary to bring out the detailed structure of these flattened cells and masses in the living condition. They stand out well in fixed preparations stained in a combination of Delafield's haematoxylin and acid fuchsin, or iron haematoxylin and acid fuchsin (figs. 12, 13, 14, Pl. 60).

In drop preparations kept alive in sea water over a period of 4, 6, 10 hours, we see stages in the formation of denser cell aggregates. The less dense of these show that actual fusion has occurred between the leucocytes of the aggregates. Fixed and stained preparations bear out this statement (See figs. 16, 17, Pl. 60).

Fixed and stained preparations are best for detailed studies on the leucocyte whether in the passive, transition, or flattened, laminate condition. The nucleus of the leucocyte so vaguely defined in the living cell, now stands out clear and distinct from the granular cytoplasm about it. The transition cell types most commonly seen are elongating cells—tapering at one pole, expanded and flattened at the other (fig. 9c, Pl. 60), or bi-polar cells tapering at both poles, the central part of the cell containing the nucleus being the widest. The tapering terminations of the cells may be withdrawn producing an almost spherical cell, or they may be extended and branched. Here, as in living preparations, the flattened cells may be seen both singly and fused. Single cells form very thin, large laminae with many slender, tapering processes (fig. 11, Pl. 60). We likewise get beautiful pictures of fusing cells (figs. 16, 17, Pl. 60), that is, of cells partially fused. More extensive membranes are seen in which no cell boundaries are discernible, the number of cells constituting the membrane indicated by the number of nuclei alone (fig. 15, Pl. 60).

The vibratile corpuscles or flagellate cells (p. 268) swim about rapidly (as may be seen in a drop preparation alive on the slide) with no rotation of the body, the flagellum beating from side to side. These cells, like the leucocytes, fuse with one another. Fusion may take place between the cell bodies which for a time are united by a bridge, as in fig. 19 in which both flagella may still be recognized. Or the flagellum of one cell may fuse at its tip with the body of another cell, as in fig. 18 where the two cells are shown separated by the length of the flagellum. In the loose complex shown in figure 20 fusion has evidently occurred in some cases by means of processes sent out from the cell bodies, in other cases between a flagellum at its tip and a cell body. No pictures indicating the fusion of the two flagella by their tips were obtained.

The complex formed by fusion of the vibratile corpuscles may be loose, as in figure 20, this condition doubtless representing an early phase in the fusion. Or the fusion may have progressed so far, the cells having been drawn together, that cell boundaries only exist in a very partial degree, as in fig. 21, where in the case of some cells there is no separation at all between the original bodies while in other cases the cell bodies are separated, but only imperfectly, by vacuole-like spaces.

Fusion may occur between very many of these cells in such a way as to establish beautiful reticula (fig. 20, Pl. 60). Vibratile cells, unlike the leucocytes, are slow to fuse, remaining active for some hours (four, six, or more hours).

The fusion of vibratile corpuscles, i.e., flagellate cells, has not been described by the authors cited, nor have I found any reference to it in the literature.

*Behavior of the corpuscles, as learned from sections, when aggregated into dense masses*

The histological question of primary interest in the aggregation of cells, whether the aggregate be massive or a thin flattened expansion, is whether the cells actually undergo cytoplasmic fusion or merely cohere. A brief review of the literature bearing on this problem is here inserted.

Geddes and all subsequent authors grant to the leucocytes the property of aggregation or agglutination, but opinions differ as to whether actual fusion of cells occurs within the aggregate. Geddes (1880) presents an interesting, and, I believe, accurate account of plasmodium formation, i.e., complete cytoplasmic fusion of the amoebocytes (leucocytes). Plasmodia, so formed, he says, contain the amoebocytes with granules (spherules, inclusions). Cuénnot (1891) says, amoebocytes "unite by their long pseudopodia and form large plasmodia visible to the naked eye, which include all of the floating corpuscles save the vibratile corpuscles." Michel (1888), studying the lymph cells of *Lumbricus*, endeavors to disprove "the reality of a complete fusion into a plasmodium." He agrees that the lymph cells undergo a change in form on contact with air, elongate, ramify, and adhere to form masses which either die at the end of several to twenty-four hours, or dissociate into distinct rounded elements, each with a nucleus. Theél (1896) made the same observations as Geddes and Cuénnot. Goodrich (1919) agrees with Michel "that the cells do not really lose their identity (1888:22), are merely connected by their hyaline ectoplasmic layer,

and are capable of resuming their independence under certain conditions." Kindred (1921), studying *Arbacia*, makes this statement: "I was unable, however, to observe whether or not the leucocytes formed true plasmodia or only *aggregate* plasmodia." He may be quoted as saying in 1925 "Another activity of the leucocytes is the formation of plasmoidal masses . . . formed by the fusion of active leucocytes," but the observations recorded do not make evident such a conclusion. Fauré-Fremiét (1925) describes, for *Arenicola marina*, the transformation of leucocytes from passive to active phase, and the agglutination of these cells to form aggregates or masses. He finds no actual cell fusion in the mass. And he states that the constituent elements of the mass tend to recover their specific morphological characters. In his comprehensive work of 1927 (dealing with many invertebrate types: *Arenicola marina*, *Amphitrite Johnstoni*, *Nereis*, *Glycera*, *Lumbricus*, *Maja squinado*, *Phascolosoma*, *Asterias rubens*, *Marthasterias glacialis*, *Asterina gibbosa*, *Paracentrotus lividus*, *Echinocardium cordatum*, *Synapta inhaerens*, *Mya*, etc.) I cannot find a definite statement as to whether actual cytoplasmic fusions take place or not, i.e., fusions between the leucocytes. His statement to follow would suggest that complete fusion does not occur. He says the agglutinated masses remain perfectly alive, and the amoebocytes are capable of returning to their initial state. A more recent investigator, Lison (1930), agrees with Fauré-Fremiét as to the reversibility of the transformation from passive to active phase. He says, however, some cells never return to the passive (quiescent) state but remain elongate and anastomose with other cells of the same type to form a kind of reticulum. But he thinks it probable that these cells die before being able to return to the passive state. My observations here recorded are in line with those of Geddes and Cuénod, as regards the complete cytoplasmic fusion of leucocytes to form a multi-nucleate mass (syncytium).

As already said, the leucocytes come together and cohere in the passive and transitional phases. Actual fusion between the leucocytes occurs, as recorded, in the active phase. Perivisceral fluid when transferred from the perivisceral cavity to an open watch glass containing filtered sea-water immediately forms a "ropy" mass which can be induced to form rounded aggregates (balls) of various sizes, simply by shaking the glass so as to bring the cells and small aggregates together. Or if the fluid be allowed to stand in the watch glass, small aggregates of cells form on the bottom of the glass and fusions occur between the aggregates which approximate each other, much as between the denser

aggregates on the slide (drop preparations). Such masses, especially the larger ones, can be kept alive and healthy in filtered sea-water for one week and longer. I have kept them two weeks. These larger, rounded masses, if they come to lie near one another, fuse or merge into a single mass by means of filose pseudopodia which project from each mass. This has been described by Ward (1933). (Ward describes this phenomenon as occurring during the first day after the lymph was extracted. I have found the seven day masses merging to form a single mass and continuing to live for another week.)

The spheroidal or sub-spheroidal masses (one to several millimeters in diameter), so formed, were preserved (in Bouin) at intervals ranging from 5 minutes to 7 days after the fluid was extracted, sectioned ( $2\text{--}4\mu$ ), stained (Delafield's haematoxylin and acid fuchsin or iron haematoxylin and acid fuchsin), and mounted. A mass preserved 5 minutes after the extraction of the perivisceral fluid shows an interior of leucocyte tissue in which amoebocytes with spherules and vibratile corpuscles are held. The leucocyte nuclei are strewn in a reticular material, the strands of which are coarser and more deeply stained, finer and less deeply stained (fig. 22, Pl. 60). The fine strands occupy meshes made by the coarser. But there are meshes of considerable size containing no visible structures. In places the picture might be taken to indicate that cells are still marked out, perhaps imperfectly fused. But in many places this is not so, and the nuclei lie distributed in a reticulum which seems to be perfectly continuous. In this tissue then, we see strands and meshes larger and smaller. The strands coarser and finer represent the cytoplasm to which will often be added an additional aggregation of cytoplasm immediately around the nucleus. Thus in this tissue the total amount of cytoplasm as compared with vacuolar space is relatively small.

The meshes of the reticulum decrease in size, and the network gradually becomes more uniform. This difference is noticeable in masses fixed after 10 to 30 minutes (fig. 23, Pl. 60), and much more marked in masses fixed after 4, 6, 8, 10, 12 hours. The appearance of the tissue during this period changes materially. Figure 24, Pl. 60, shows the central part of a section through a mass preserved 6 hours after the perivisceral fluid was drawn. We no longer see between and around the nuclei a reticulum of quite coarse and much finer fibers, with meshes varying correspondingly in size. Instead, we find stretching between the leucocyte nuclei a reticulum made up of strands all much alike and all delicate. In such masses the reticulum is, one would say, uniform,

the strands all fine, the meshes all small; and there is nothing which can be construed as leucocyte cell boundaries. The meshes become progressively smaller as the masses grow older. And in masses which were kept alive and fixed after 2, 4, 6 and 7 days, the cytoplasm is very dense, and looks granular, becoming more and more so with the length of life of the mass. Thus in these older masses we find a dense syncytium of granular appearance in which nuclei lie scattered. A discussion of the vibratile corpuscles and cells with spherules held in the leucocyte tissue will follow.

The vibratile cells may be distinguished from leucocyte tissue by reason of their affinity for Delafield's haematoxylin. In the earlier masses these cells lie scattered throughout the mass, singly or occasionally in groups. As the mass becomes older, we note the more frequent occurrence of groups of vibratile cells, as if preliminary to fusion between these cells. In masses of several days, extensive tracts of vibratile cell tissue are seen merged with the general syncytium. In such tracts no cell boundaries are visible.

In 5 minute masses the cells with spherules all appear as spheroidal structures. Later, we note what seems to be a wandering of these cells, in general toward the periphery of the mass. This tendency becomes noticeable in masses as early as 6 to 8 hours after withdrawal of the fluid (fig. 25, Pl. 60), and becomes more pronounced up to the 10 hour age, when we get these cells massed at the periphery (fig. 26, Pl. 60), many of them elongate as if passing out from this zone. In some of the masses we found the margin surrounded by cells, as if they had already left the mass. In masses of 12 hours, we see fewer of these cells at the periphery, and while some of them, here and in the interior, retain their individuality, others are represented by irregular groups of spherules not marked off from the general cytoplasm. Also, there is to be seen an occasional cell of this type in a vacuole. In considerably older masses (2, 4 days), more and more groups of spherules occur free in the general syncytium. The spherules now vary greatly in size, some much larger than the original ones, others smaller grading down to mere granules. Doubtless then as the cell loses its identity, fusion between some of the inclusions occurs, larger bodies thus being formed while digestion would account for the diminutive size of others (fig. 29a, Pl. 60). In still older masses (6 and 7 days) cells with spherules are virtually absent, and in their place we find only scattered spherules grading down to granules (fig. 29b, Pl. 60). The pictures then indicate that a considerable number of the cells with spherules escape from the

mass, but that others remain in it losing their identity, their cytoplasm merging with that of the general syncytium, and the inclusions of these latter cells undergo a process of digestion.

The peripheral zone in these masses shows points of interest. The earliest masses are rough and irregular in contour, and in the masses of several hours the general leucocyte tissue at the periphery throws out delicate filose pseudopodia (fig. 27, Pl. 60). In slightly older masses of 6, 7, 8 hours we do not find the filose terminations, but in their stead a bounding line (as seen in sections) of dense cytoplasm (figs. 25, 32, Pl. 60). The surface of the 10 hour mass (fig. 26, Pl. 60), however, appears much as does that of the region of the 4 hour mass shown in fig. 27, Pl. 60. The superficial layer of cytoplasm, recorded for the 6-8 hour masses, is seldom present in masses of this age. Masses of 12 hours, on the other hand, are smooth showing a limiting membrane in most places as a line representing a layer of condensed cytoplasm (fig. 31, Pl. 60). The peripheral zone is now loosely reticulate and coarsely vacuolated, and contains considerably fewer cells with spherules than a corresponding zone of the 10 hour masses. It is evident that something has occurred within the mass to bring about this loose, vacuolated condition. And it is logical, in view of the observations, to assume that the vacuoles once held cells with spherules which migrated to and out from the periphery, leaving the reticulum loose and vacuolated. In masses of several days, the cytoplasm of the mass is dense out to the surface, and in some the peripheral zone is broken up into distinct tracts, which run parallel to the surface of the mass. These tracts may contain one, several or no nuclei, and while they bear some resemblance to the cells of an embryonic connective tissue, they do not become more distinct or more differentiated in the course of the next several days. Many of the older masses do not show these fiber-like tracts in the peripheral zone, and in view of what has been observed for the 8, 10, 12 hour masses, I feel that the breaking up of the zone in question is but the result of the migration of the cells with spherules. It may be added that there is no correlation between the tracts and the distribution of nuclei, and what resemblance the region has to cellular tissue is very superficial.

Of the previously mentioned investigators, Lison (1930) seems to be the only one who has prepared and figured section preparations of the larger cell aggregates or masses. He describes the agglutination of leucocytes in the passive phase, and the formation of a mass which appears as a solid plasmodium. His figures show the external zone of such masses to be divided into two distinct layers: a deeper fibrillar

layer oriented parallel to the surface, and a superficial layer bristling with very narrow, pointed pseudopodia anastomosing at their base to form a sort of reticulum (fig. 5, loc. cit.). The interior of the mass is so filled with coloring matter (which he had previously injected into the coelomic cavity) that its structure is hard to make out. He says cells charged with coloring matter emigrate from the deeper layer, pass across the external fibrillar layer, escape and once more become free. These emigrating elements are rounded cells with finely granular cytoplasm. He regards them as representing a phase of the leucocyte intermediate between the active amoeboid phase and the original passive phase with the "vesicular" flaps. He also says, that by the sixth day the organized structure of the mass has disappeared, the mass having broken down into separate, juxtaposed cells, almost all of which represent leucocytes in the intermediate phase.

I, on the other hand, have not been able to make any observations which would show the transformation of the leucocyte, from passive to active phase, to be a reversible phenomenon. The complete cytoplasmic fusions figured from drop preparations as well as those seen in sections would speak against the reverse transformation of active leucocytes. Nor, do I find healthy masses (denser, larger aggregates) breaking up into elements which could be regarded as the original constituents of the aggregate. I do find, however, in older masses, in which degeneration has already set in, the general syncytium breaking up into rounded elements which may contain one or more nuclei. These rounded bodies, which may be classed as cells, may be well defined or they may be less so. Some of the syncytial mass remains as it was, a syncytium (fig. 30a, Pl. 60). The cytoplasm of the cells which have separated out from the general mass is very granular, and their nuclei obviously degenerate. We often see these rounded bodies close to the surface of the mass as if they had just left it (fig. 30b). Degeneration changes are first apparent near the periphery of the mass, but in late stages of degeneration the interior is likewise affected and breaks up into rounded elements as in figure 30a, Pl. 60. Again, I say, the nuclei within the "cells" are pycnotic and the cells obviously incapable of assuming the character of the original constituents of the mass.

#### Conclusion

Evidence as to cell fusions obtained from sections is not always convincing, but certainly if cell boundaries existed in the leucocyte tissue or the vibratile cell tissue of the massive aggregates, they ought to be

visible. But they are not, and moreover, nothing is clearer than the pictures afforded by slide preparations (figs. 12, 13, 14, 15) showing complete cytoplasmic fusion between leucocytes and also between vibratile cells. Thus it seems quite clear that the fundamental feature in the formation of these lymph cell aggregates is syncytial fusion with the production of a plasmodium quite as Geddes thought.

### Summary

1. Five kinds of cellular elements are found floating in the perivisceral fluid of *Lytechinus (Toxopneustes) variegatus*: rounded amoebocytes with red, colorless or yellow-green inclusions (spherules), amoebocytes with a varying number of membranous flaps (leucocytes), and vibratile corpuscles (flagellate cells).

2. The amoebocytes undergo changes in form shortly after their removal from the coelomic (perivisceral) cavity. Cells with inclusions (spherules) become amoeboid, slip and slide over each other with no resulting fusion or coherence; they may however become entangled among or captured by the amoebocytes with membranous flaps (leucocytes), but never fuse with them. The leucocytes take on another habitus, almost immediately upon their extraction, flattening out as very thin laminae with many processes. These cells fuse to form bi-, tri-, and multi-nucleate masses, even extensive sheets or membranes on the slide. Leucocytes cohere in the passive (quiescent) state, as well as in stages transitional between the passive and active (flattened, laminate) form. Vibratile corpuscles are very active. They fuse to form reticula and sheets of tissue composed of vibratile corpuscles alone. The flagellate cells are slow to lose their activity and to fuse.

3. Denser aggregates (lymph "balls" or masses), which have been kept alive in sea water, preserved at intervals, and then sectioned, show the series of internal changes. The question is, do the cells constituting the aggregate fuse, as do those on the slide, or are they but closely applied, later separating into cells much like those originally forming the aggregate? Section preparations of larger aggregates, fixed at intervals ranging from 5 minutes to 7 days, all show conclusively that actual fusion between the leucocytes is accomplished, and that the mass breaks up into rounded uni- or multi-nucleate masses only after degeneration has set in. These degeneration masses ("cells") bear no resemblance to the original cellular constituents of the mass. (They cannot be reconciled with the intermediate phase of the leucocytes described by Lison 1930.) The nuclei of the degeneration masses are

pycnotic, and the rounded masses in their entirety obviously degenerate. The amoebocytes with inclusions (spherules) either migrate to and out from the surface of the mass, becoming free or, remaining in the mass, lose their individuality as cells, their cytoplasm merging with that of the mass, and the inclusions are finally digested down to minute granules. Vibratile corpuscles eventually fuse and merge with the cytoplasm of the general mass.

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<sup>3</sup> For a more complete list of the literature bearing on development of the sponge larva, consult the literature references appended to Wilson, H. V. (1935).

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#### EXPLANATION OF PLATES 56-60

(Plates 56-59 are from *Lissodendoryx carolinensis* material; Plate 60, except for figure 14, from *Lytechinus variegatus* material. All figures of Plates 58-60 camera drawnn.)

##### Abbreviations used in figures of plates 58-60

a-sp	antispicular pole
can	canal space
ci	cell with inclusions (spherules)
cs	coarser strands of cytoplasm
d l ep	degenerating larval epithelium
eic	emigrating inclusion cell
ep	epidermis
fs	fluid filled space
fp	filose processes
fs	finer strands of cytoplasm
l ep	larval epithelium
lm	limiting membrane
ln	leucocyte nucleus
s	syncytium
sp	spicular pole (Pl. 58, 59), space (Pl. 60)
vc	vibratile corpuscle

#### PLATE 56

Fig. 1. Median longitudinal section of free-swimming larva in which the epithelium has already been lost at the non-spicular pole. Bundle of megascleres (tylates) at spicular pole. Interior non-cellular. (16 mm.  $\times 10$ .)

Fig. 2. Lateral portion from median longitudinal section of young free-swimming larva. The figure shows the non-cellular (syncytial) character of interior of mass; tiers of small, elliptical nuclei constituting nuclear zone, and rod-like portions of epithelium. In upper part of figure, a fluid space. (Oil immersion.)

Fig. 3. Portion of median longitudinal section of free-swimming larva, showing non-spicular pole; internal syncytium and nuclei; lateral epithelial stratum; metamorphosis already begun at non-spicular pole, at which end there is a single layer of epithelial nuclei lying quite at the surface. A fluid tract or two is to be noted. (Oil immersion.)

Fig. 4. Portion of median longitudinal section through non-spicular pole showing an earlier stage in metamorphosis of epithelium than that seen in figure 3: several layers of epithelial nuclei, these approaching but not lying at the surface; rod-like portions of epithelial cells still present but much shortened

and thickened; interior of the mass very dense and granular reticular (syncytial). (Oil immersion.)

Fig. 5. Vertical section of attached and flattened 24 hour larva in which the larval epithelium has completely disappeared as such. Epithelial nuclei have moved from periphery, some of them now lying in interior. Interior dense, compact, and unbroken into cells. Some epidermal cells already at surface but not a continuous stratum; surface in general bounded by a limiting membrane which is simply the outermost layer of syncytium. (Oil immersion.)

#### PLATE 57

Fig. 6. Lateral portion, near spicular end, of median longitudinal section of larva retarded in metamorphosis. Interior breaking up into cells in vicinity of megascleres. (Oil immersion.)

Fig. 7. Section showing non-spicular pole of same larva as in figure 6. This end unbroken into cells; its tissue vacuolated. (Oil immersion.)

Fig. 8. Region from interior of attached larva (vertical section) which has been invaded by bacteria. Interior broken up into rounded cells (mesenchymal) containing a number of epithelial nuclei. Presumably, larva had attached and flattened prior to invasion by bacteria. (Oil immersion.)

Fig. 9. Vertical section of retarded larva which had attached and flattened. Interior almost completely broken up into cells with distinct membranes; larval epithelium retained at the surface in places; between such patches of epithelium an epidermis present or in process of formation. Epidermis present over most of surface of attachment. (Oil immersion.)

Fig. 10. Portion from vertical section of attached larva invaded by bacteria. Bacteria appear in central part of photograph. Cytoplasm rounded up about nuclei to form large cells with distinct boundaries. Much of what was body now occupied by fluid and abundant bacteria. Most of the cells contain degenerate epithelial nuclei (not distinct in photograph), and we often get cells within cells. (Oil immersion.)

Fig. 11. Lateral region from median longitudinal section of free "oedematous" larva. Fluid has accumulated in these larvae, filling large interconnecting spaces, between which lies what remains of the once syncytial interior; interior now broken up into rounded cells with distinct outlines. Not only the interior but the exterior as well is in process of breaking up into cells, some of which are passing out from the mass. (Oil immersion.)

#### PLATE 58

Fig. 1. From a median longitudinal section of free-swimming larva showing non-spicular pole. At the left a bit of larval epithelium (*l ep*), to the right of this a single row of epithelial nuclei at or very near the surface, these nuclei indicating that metamorphosis of the epithelium at this pole is far along. Note dense, compact nature of interior and presence of non-nucleolate nuclei a short distance below surface.  $\times 1000$ .

Fig. 2. From median longitudinal section through spicular pole. At the right

a bit of larval epithelium and to the left of this the unciliated spicular pole; non-nucleolate or epidermal nuclei at or very near the surface of this pole. Occasionally an epidermal cell is well marked out (right of figure). Interior of larva non-cellular and granular-reticular.  $\times 1000$ .

Fig. 3. Portion of longitudinal section through spicular pole (*sp*) of a larva not yet liberated from parent tissues. At surface of this pole an epidermis consisting of elongate, columnar cells. Aside from this feature the section is similar to figure 2.  $\times 1000$ .

Fig. 4. Portion from another median longitudinal section of a free-swimming larva. Region figured is from non-spicular pole and shows a single tier of epithelial nuclei at this pole. The figure is included chiefly to show extrusion of epithelial nuclei at surface.  $\times 1000$ .

Fig. 5. From median longitudinal section of free larva, figuring non-spicular pole. Several tiers of epithelial nuclei present at this pole, the rods still *in situ*, though somewhat shortened and thickened. The figure represents an earlier stage in metamorphosis of the epithelium than that shown in figures 1 and 4, Pl. 58.  $\times 1000$ .

Fig. 6. Portion of vertical section of attached and flattened larva. Interior of mass still syncytial, continuous and dense; limiting membrane (*lm*) in general only the outermost layer of the syncytium, but two epidermal cells are already well marked out.  $\times 1000$ .

Fig. 7. Peripheral region of vertical section from attached and flattened larva, which is being broken up by watery accumulations into strands and tracts. These begin to bear a resemblance to freely connected and vaguely outlined cells.  $\times 1000$ .

Fig. 8a. Diagram of vertical section of flattened attached larva figured in 8b. No cellular differentiation or canal spaces.  $\times 102$ .

Fig. 8b. Portion of vertical section of flattened attached larva (diagram 8a) which has begun to undergo cellular differentiation and formation of canal spaces. Note great number of degenerate epithelial nuclei.  $\times 1000$ .

Fig. 9. Portion of vertical section of attached and flattened larva in which canal spaces have appeared. As yet no well-defined layer of cells at the surface and the limiting membrane (*lm*) which appears as a line, is but the outermost extension of the internal syncytium. Interior of mass very generally interrupted by watery spaces marking out vaguely delimited cells. Canal spaces bounded in part by the general syncytium, and in part by cells already marked out.  $\times 1000$ .

Fig. 10. From lateral part of median longitudinal section of free-swimming larva showing nature of epithelium (larval epithelium).  $\times 1000$ .

Fig. 11. Diagram of vertical section of flattened attached larva which has undergone some cellular differentiation and formation of canal spaces.  $\times 102$ .

Fig. 12. Small portion of vertical section of flattened sponge, showing canal spaces bounded in part by cells already differentiated out of the general syncytium.  $\times 1000$ .

#### PLATE 59

Fig. 13. Surface view of retarded free larva. Such a larva is characterized by a greater area of epidermis (light area in the figure) than is found in normally developing free larvae. *sp*: spicular pole.  $\times 70$ .

Fig. 14. Portion of median longitudinal section of retarded larva, showing transition between the epidermis of spicular pole and the larval epithelium (*l ep*) found over the remaining surface of larva. Epidermis here well defined at spicular pole (compare epidermis of a normally developing free larva, fig. 2, Pl. 58); interior in vicinity of megascleres broken up into cells (unlike normal larva); these cells large and well defined; tissue nearer the spicular pole is continuous and compact.  $\times 1000$ .

Fig. 15. Small region in vicinity of megascleres of a retarded larva. Part of megasclere at bottom of figure; the general syncytium almost completely broken up into cells; mesenchymal (nucleolate and non-nucleolate) nuclei within these cells.  $\times 1000$ .

Fig. 16. Portion of section from retarded larva (7 days old), loosely attached along one side, and yet retaining larval shape. Region figured is near the non-spicular pole (there was early metamorphosis of epithelium at this pole in these retarded larvae); larval epithelium (*l ep*) at the left of figure; location, arrangement, and shape of the elements here show that they represent outer ends of original rods which have fused with one another from within out. Epithelial nuclei no longer massed to constitute a nuclear zone, but are scattered in interior; non-nucleolate (epidermal) nuclei at some little distance below rod remnants.  $\times 1000$ .

Fig. 17. From section of loosely attached retarded larva. Portion figured shows remnants of larval epithelium at the left; some of the rods extending for some distance into the larva, others very short, wide structures; epithelial nuclei still massed near periphery, showing that the stage in metamorphosis is an earlier one than that of figure 16; non-nucleolate nuclei scattered among the epithelial nuclei; epidermis forming at right and at extreme left of figure.  $\times 1000$ .

Fig. 18. Portion of vertical section of very flattened and firmly attached larva (7 days old) showing both upper and lower surfaces. Remnants of larval epithelium (*l ep*) retained in places (resembling the same shown in figures 16, 17); between such remnants epidermal cells already formed (left) or in process of formation; in region figured, almost no epithelial nuclei near the surface; non-nucleolate nuclei in considerable numbers near the surface; interior almost entirely broken up into cells in this larva, cells of same type as in figures 14, 15.  $\times 1000$ .

Fig. 19. Portion of spicular pole of "oedematous" free larva, as seen in longitudinal section. Cells and cell-like masses lacking nuclei budding off at surface (bottom of figure); cells also being budded off into fluid-filled space (top of figure).  $\times 1000$ .

Fig. 20. From vertical section of "oedematous" larva showing lateral surface (top of figure). Outer layer of larva, like the interior, breaking up into cells, these small and rounded containing epithelial nuclei and passing out from surface. Such nuclei, and also those in the unbroken portion of periphery all pyrenotic.  $\times 1000$ .

Fig. 21. From similar section through anti-spicular (non-spicular) pole (*a sp*), surface of larva at bottom of figure. A fluid-filled space (*jfs*) in interior of larva almost isolates a superficial layer from interior. This layer repre-

sents original larval epithelium together with some of adjoining syncytial interior. Here, as in figures 19, 20, cells are being budded off to exterior, and into fluid-filled space of interior; nuclei all pycnotic.  $\times 1000$ .

Fig. 22. Several mesenchymal cells from interior of "oedematous" larva. Note the uniformity in shape and size and pycnotic character of nuclei.  $\times 1000$ .

Fig. 23. Pycnotic nuclei from "oedematous" larvae. Smaller nuclei are epithelial; larger, mesenchymal.  $\times 1000$ .

Fig. 24. Cells and masses from interior of larvae invaded by bacteria. Cells large and with distinct ectoplasmic membranes, usually containing a number of degenerate epithelial nuclei (a). We often get cells within cells, or cells within outer non-nucleated layers of cytoplasm (b).  $\times 1000$ .

Fig. 25. Pycnotic epithelial nuclei from flattened attached larvae slow to undergo cellular differentiation and formation of canal spaces.  $\times 1000$ .

Fig. 26a. Megascleres, tylotes.  $\times 474$ .

Fig. 26b. Microscleres, sigmata.  $\times 734$ .

Fig. 26c. Microscleres, isochelae.  $\times 734$ .

Fig. 26d. Microscleres, sigmata.  $\times 734$ .

#### PLATE 60

Fig. 1. Amoebocyte with red inclusions (spherules). Cell as it appears immediately upon removal of perivisceral fluid from body cavity. Living preparation.  $\times 310$ .

Fig. 2. Amoebocyte with colorless inclusions (spherules), as it appears immediately upon extraction of perivisceral fluid. Spherules are somewhat larger than those in red cell (fig. 1). Living preparation.  $\times 310$ .

Fig. 3. Amoebocytes with yellow-green inclusions (spherules). This cell smaller than red or colorless cell. Living preparation.  $\times 310$ .

Fig. 4. Leucocyte (amoebocyte with membranous flaps) as it appears *immediately* upon extraction of perivisceral fluid. Nucleus surrounded by a number of non-granular cytoplasmic flaps, which go out from any part of cell. Flaps so transparent that it is only the edge which catches the eye. Living preparation.  $\times 310$ .

Fig. 5. Vibratile corpuscle or vibratile cell as it appears with ordinary methods of illumination. Whip-like flagellum *four* times as long as diameter of cell body. Living preparation.  $\times 480$ .

Fig. 5'. Vibratile corpuscle viewed with dark field. Flagellum in reality blade-like. Living preparation.  $\times 310$ .

Figs. 6a, b, c, d, e. Amoebocyte in process of becoming amoeboid. First a bleb-like protrusion of the cell, consisting of non-granular, hyaloplasmic substance, is noted (a), then several blebs in rapid succession (b and c), until finally one bleb becomes larger than the others (d) and the spherules then flow into it as the cell begins to move about by amoeboid motion. The two cells labeled (e) are actively amoeboid cells. Living preparations.  $\times 310$  (a, b, d, e);  $\times 480$  (c).

Fig. 7. Very elongate amoebocyte with inclusions showing pseudopodium and nucleus of cell. Fixed preparation.  $\times 656$ .

Fig. 8. Two figures showing amoebocyte with inclusions captured by leucocyte. Living preparation.  $\times 310$ .

Figs. 9a, b, c. Early stages in transformation of leucocytes *in vitro*, as seen both in living and in fixed preparations.  $\times 656$ .

Figs. 10a, b. Cohering leucocytes. Leucocytes may come together and cohere before they have changed their habitus. Fixed preparation (seen also in the living).  $\times 656$ .

Fig. 11. Leucocyte which has flattened out on surface of slide. It now appears as a very thin lamina with many processes, the nucleus being surrounded by a narrow zone of granular material. Living preparation.  $\times 656$ .

Fig. 12. Bi-nucleate lamina. Two leucocytes have fused. No line of demarcation between the cells, fusion complete. Fixed preparation.  $\times 656$ .

Fig. 13. Tri-nucleate mass of leucocyte tissue. Complete fusion between three leucocytes. Fixed preparation.  $\times 656$ .

Fig. 14. Denser aggregate or multinucleate mass of leucocyte tissue—a small "clot." Fixed preparation. (*Arbacia punctata*).  $\times 656$ .

Fig. 15. Extensive membrane or sheet of leucocyte tissue. Number of leucocytes constituting mass indicated by number of leucocyte nuclei. There has been complete fusion of constituent cells. Fixed preparation.  $\times 656$ .

Fig. 16. Two flattened, expanded cells in process of fusing. Certain of the cell processes have come in contact and there fused. Such cells would eventually become a single bi-nucleate mass. Fixed preparation.  $\times 656$ .

Fig. 17. Group of six leucocytes which have made contact with one another and are in process of merging to form a single mass. Fixed preparation.  $\times 656$ .

Fig. 18. Two vibratile corpuscles, separated by the length of the flagellum, but united. The flagellum of one has fused with the body of the other. Early step in the formation of a reticulum or sheet of tissue composed of vibratile corpuscles. Fixed preparation.  $\times 656$ .

Fig. 19. Two vibratile corpuscles whose cell bodies are touching. Fusion has occurred at point of contact. Fixed preparation.  $\times 656$ .

Fig. 20. Open reticulum formed by fusion of a number of vibratile corpuscles. Fixed preparation.  $\times 656$ .

Fig. 21. A more dense reticulum of vibratile corpuscles. Fixed preparation.  $\times 656$ .

Fig. 22. Part of section from lymph mass preserved 5 minutes after perivisceral fluid was extracted. The section shows a number of leucocyte nuclei. Between these there is material marked by irregularly coursing strands connected with one another. In the meshes formed by these strands sometimes a finer reticular structure can be made out. Elsewhere no structure is visible in the meshes. In places coarser strands bound areas which might be taken to represent leucocyte cells, but in most places cells cannot be visualized and the nuclei lie in a reticulum which seems to be perfectly continuous. In most places, a little cytoplasm appears about the leucocyte nucleus. The section shows two inclusion cells. Inclusion cells and vibratile corpuscles have preserved their individuality.  $\times 656$ .

Fig. 23. Part of section of lymph mass preserved 30 minutes after perivisceral fluid was extracted. Meshes of reticulum in this section for the most part

smaller, and reticulum more obviously continuous than in the preceding. Section shows a vibratile corpuscle (*vc*).  $\times 656$ .

Fig. 24. Part of section from 6 hour mass. The syncytial material now shows pretty uniform meshes, the strands all much alike and delicate. Several inclusion cells shown in figure. These cells still retain their individuality, as do also the vibratile corpuscles (*vc*).  $\times 656$ .

Fig. 25. Periphery of 8 hour mass (in section). The leucocyte tissue which forms framework of mass very like that of 6 hour mass. Quite a number of cells with inclusions have come to lie near periphery. They have retained their individuality. Surface of mass made by continuous film, and in that sense is smooth, the limiting membrane being merely the outermost extension of the reticulum of leucocyte tissue.  $\times 656$ .

Fig. 26. Peripheral region (in section) of 10 hour mass. The emigration of cells with inclusions to periphery, begun as early as 6 hour mass, has reached point where cells with inclusions are leaving the mass by amoeboid movement. These outwandering cells have broken the limiting membrane in a great many places and we now get filose processes at the surface. Note crowded cells with inclusions a short distance below surface of mass.  $\times 390$ .

Fig. 27. Peripheral region of 4 hour mass (in section). This section figured to show that the "balls" have not yet, in places, gotten a smooth, film-like surface (fig. 25). These masses still retain in places, as figured, filose processes.

Fig. 28. Part of interior (as seen in section) of mass preserved after 2½–3 days in culture. Reticulum which now stretches between leucocyte nuclei very finely reticular.  $\times 656$ .

Fig. 29a. From section of 4 day mass showing a bit of the interior. Interior very finely reticular. Cells with inclusions no longer retain their identity, i.e., the cell membranes have disappeared, and inclusions have in some cases fused (merged). The section shows a number of these masses of varying size, ranging from large to quite small structures. Two of them lie in what appear to be small collections of fluid.  $\times 656$ .

Fig. 29b. From section of 6 day mass showing a bit of the interior of the mass. Interior very finely granular-reticular, and what remains of the inclusion cells lie free in the syncytium. Remnants of inclusions appear to be in the process of digestion, grading down to fine granules.  $\times 656$ .

Fig. 30a. Part of section from mass (1 week old) which is dying. Section includes surface, most of which shows a continuous limiting membrane (*lm*). The now dense, granular cytoplasm of the mass, is rounding up about nuclei and forming rounded cell-like bodies. The nuclei within the cell bodies all appear pyenotic. This breaking up of interior into cells, a phenomenon associated with death of mass.  $\times 656$ .

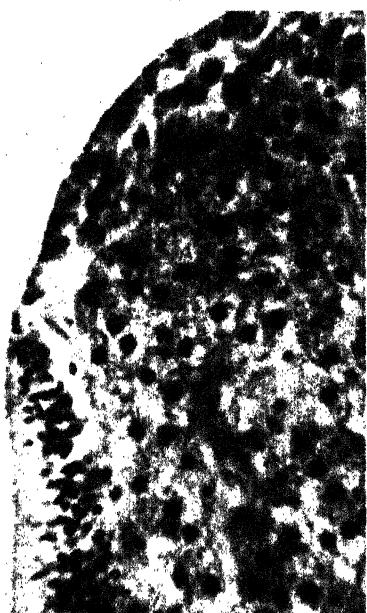
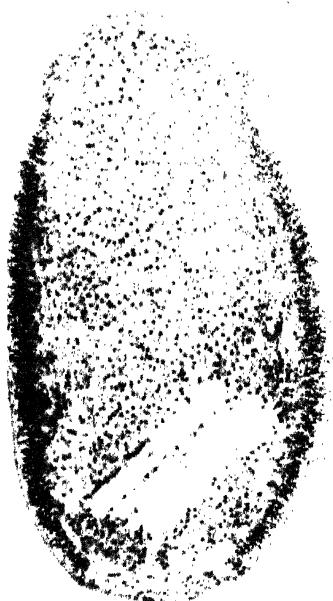
Fig. 30b. Rounded masses of cytoplasm, each containing several nuclei, lying just outside the mass shown in 30a. The nuclei within these outwandering masses are all pyenotic.  $\times 656$ .

Fig. 31. Peripheral region of 12 hour mass as seen in section. Reticulum which stretches between leucocyte nuclei in this section loose and irregular. It

shows some spaces of considerable size (*sp*). The spaces apparently represent cavities in which inclusion cells lay before emigrating from the mass. Emigration of these cells would also account for the broken strands of the reticulum. Few inclusion cells now lie at the surface or in region near surface. Surface of mass again smooth, the filose processes absent.  $\times 656$ .

Fig. 32. Peripheral region of older mass (4 days old) as seen in section. Surface smooth, interior unbroken (syncytial). A few cells with inclusions still lie in this region. These cells have, however, lost the cell membrane over a part or all of the surface. Section also shows a vibratile corpuscle.  $\times 656$ .

PLATE 56



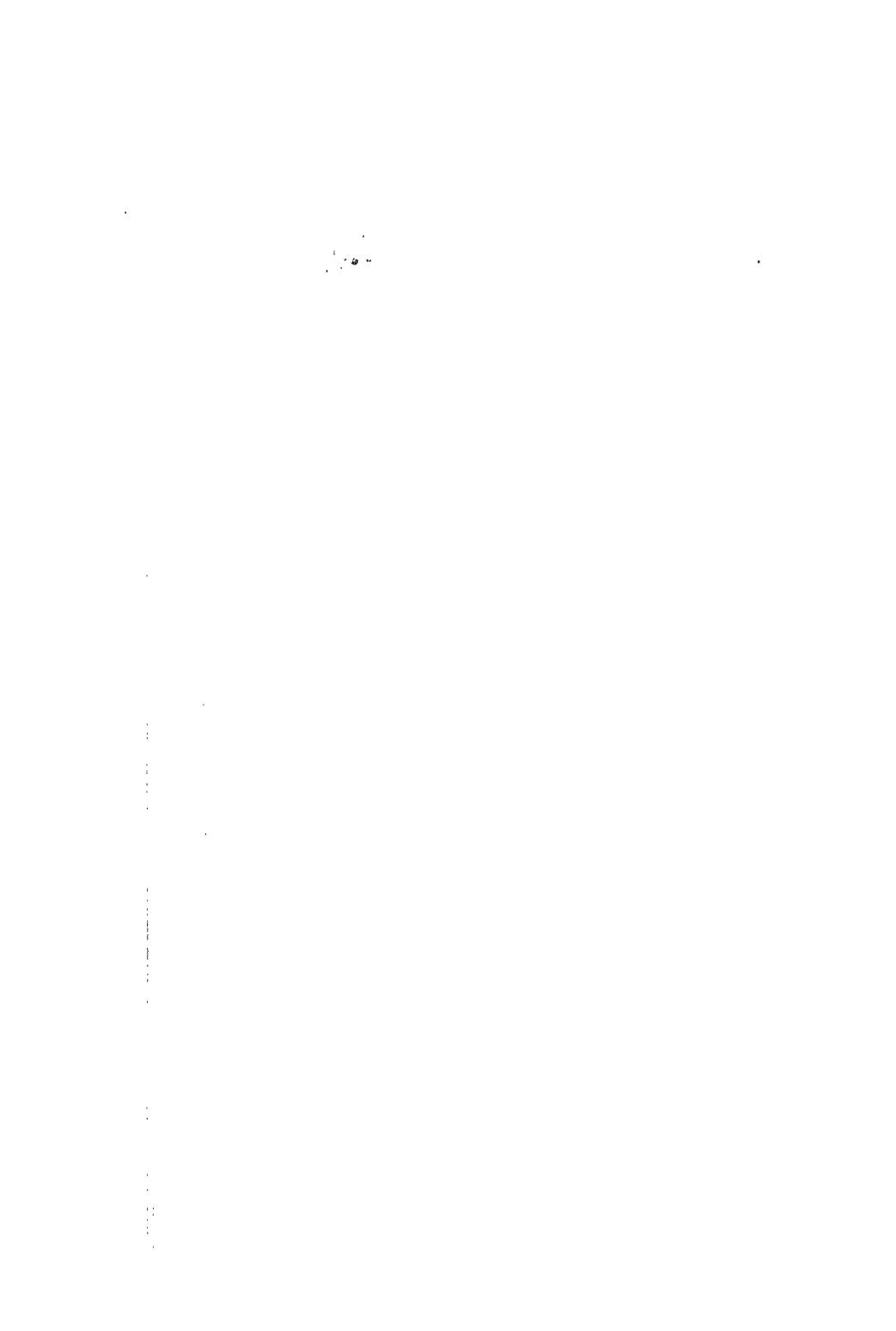
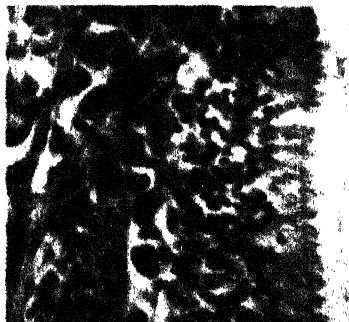


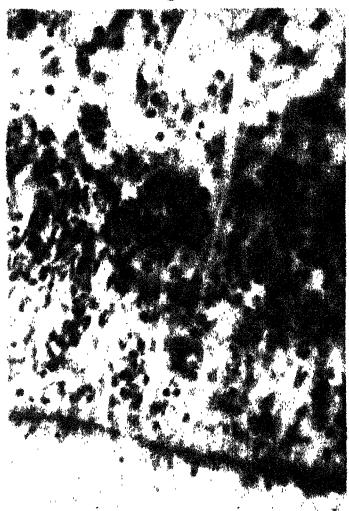
PLATE 57



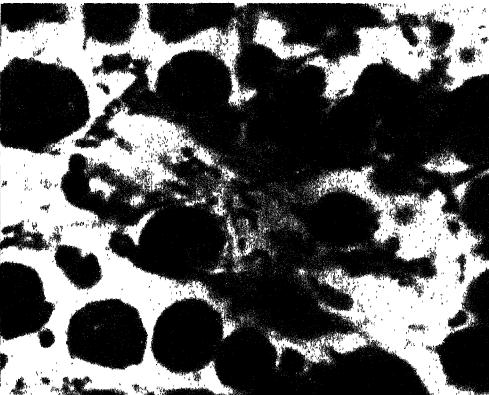
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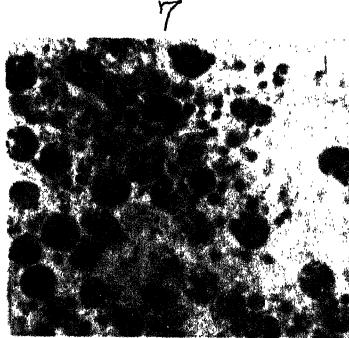
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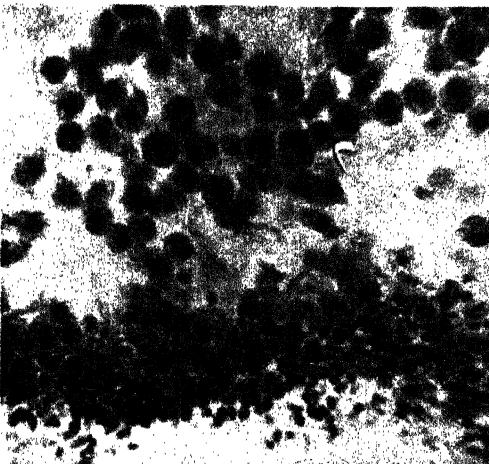
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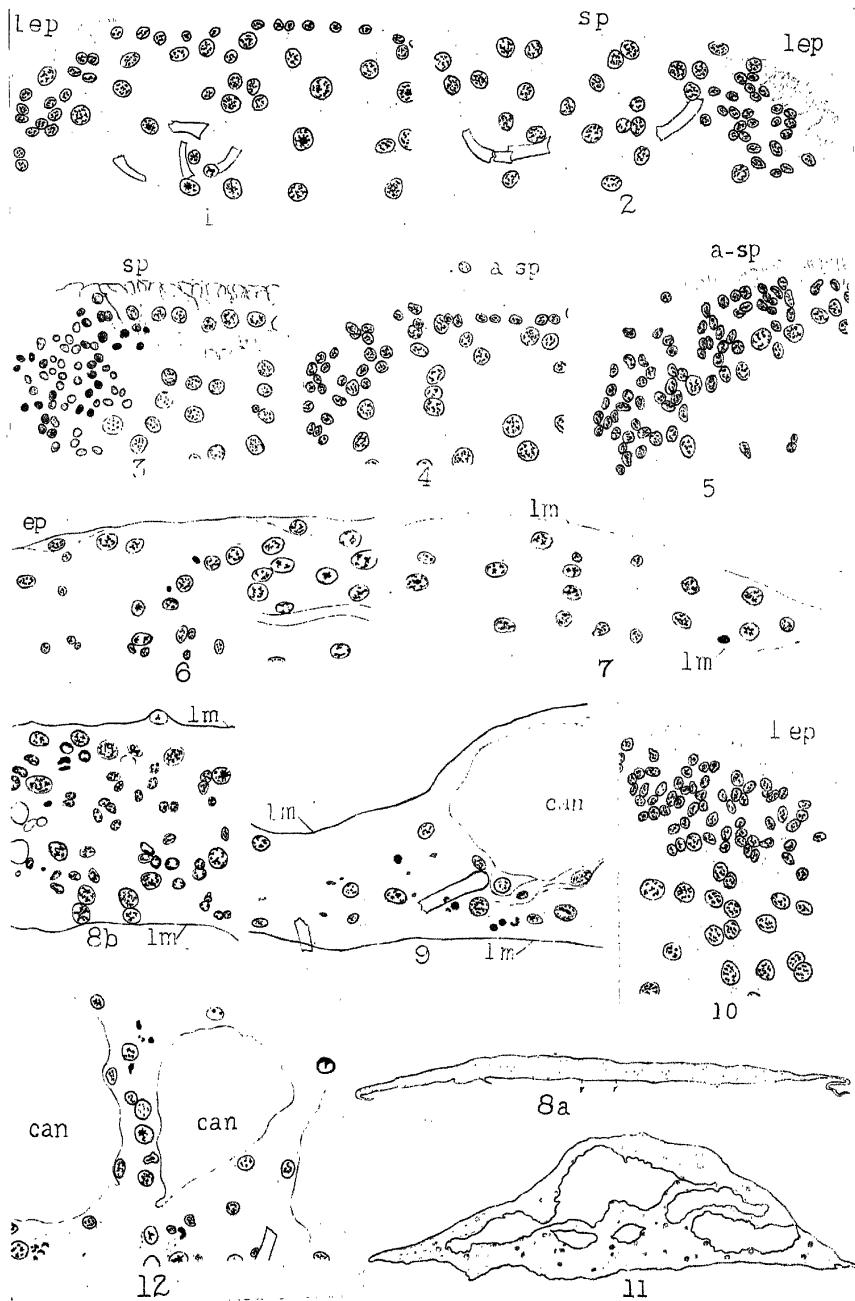
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PLATE 58



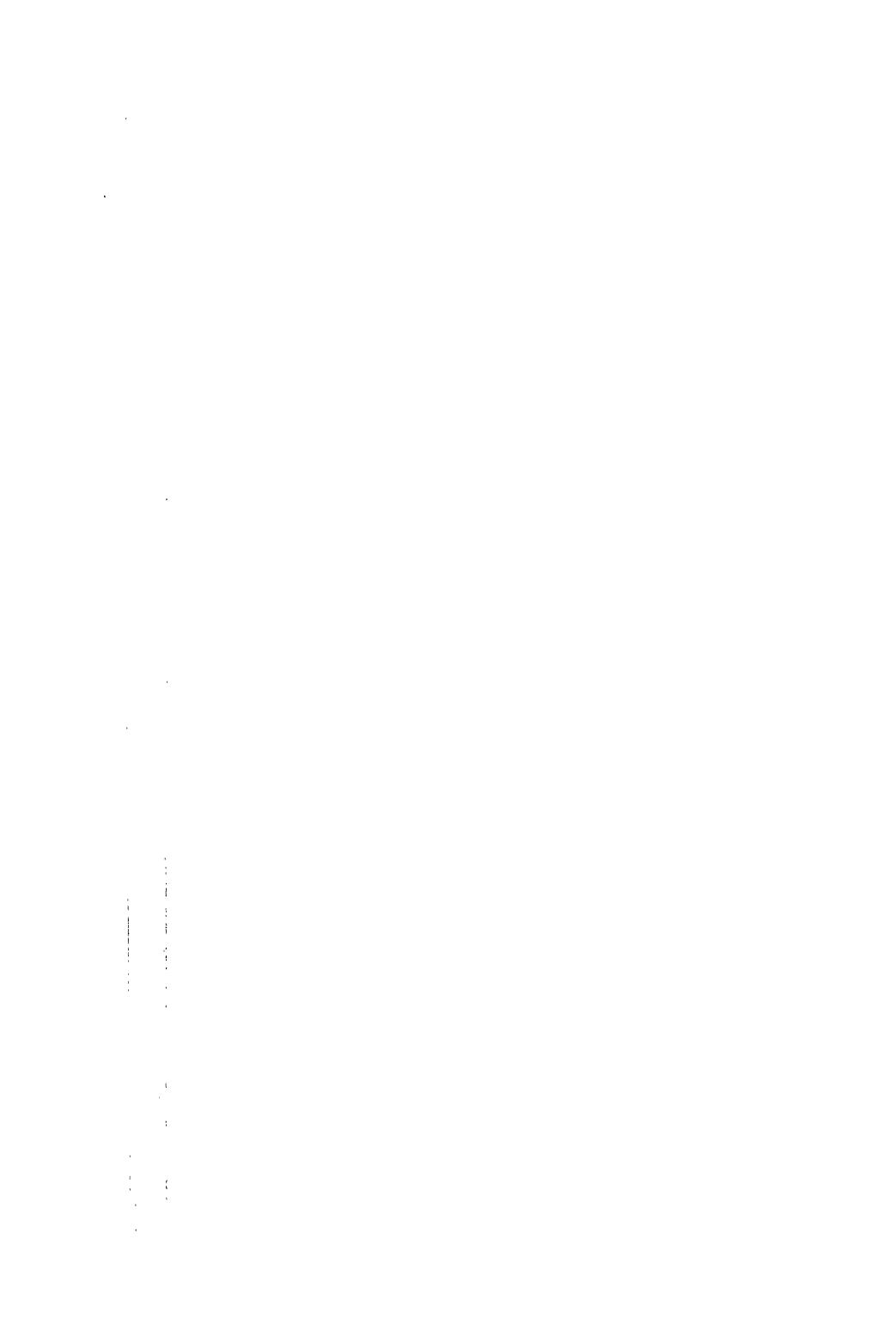


PLATE 59

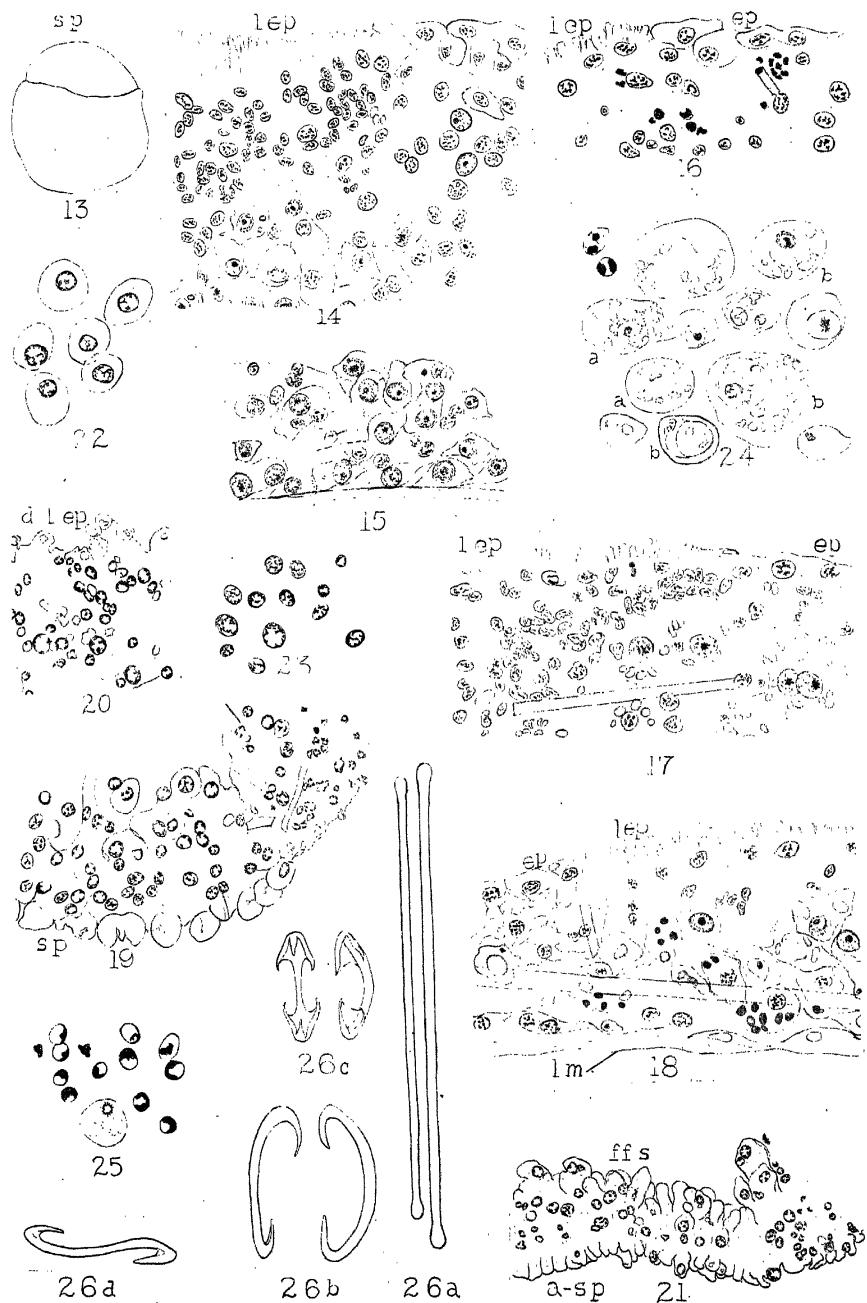
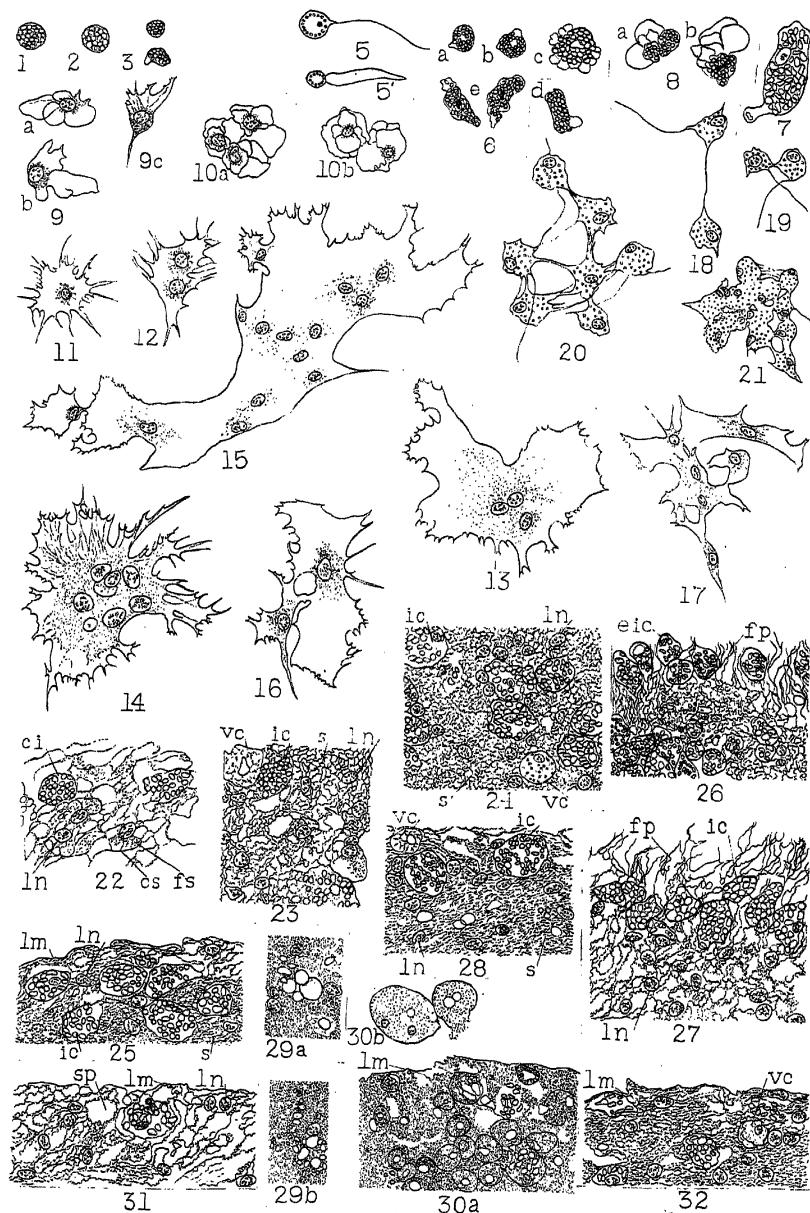




PLATE 60





## A SPECTRO-COMPARATOR FOR THE STUDY OF HEMOGLOBIN

By F. G. HALL

### PLATE 61 AND ONE TEXT-FIGURE

A method for the spectroscopic study of hemoglobin in dilute solutions was described a year ago (Hall, Jour. Physiol. **80**: 502. 1934). Since that time a few modifications have been made that seem to simplify such a method and increase its accuracy. For these reasons they are now described.

#### THE MICROSPECTROSCOPIC COMPARATOR

A Zeiss microspectroscopic eyepiece attached to a Hastings pH colorimeter (Bausch and Lomb) is shown in the photograph (pl. 61). The ocular and prisms, as well as the cups and plunger on one side, are removed from the colorimeter. A brass tube in which a 6 volt mazda bulb is held is shown just below the lower cup. Oxygenated hemoglobin is placed in the upper cup and reduced hemoglobin in the lower. A few grains of sodium hydrosulphite are used to keep the hemoglobin fully reduced. The distance between cups is usually kept at 20 millimeters. The Hastings type of colorimeter has been found to be a much more convenient type than that previously employed which had a plunger attached to a movable cup. Its only disadvantage is that it requires a greater quantity of the standard solution. The change in the position of the microspectroscopic eyepiece from the vertical to the horizontal is a decided improvement.

#### THE WATER BATH

In the previous description of this method, tonometers were removed from a constant temperature bath and placed in a small glass water bath in front of the side opening of the spectroscope. A more satisfactory arrangement has been devised making it unnecessary to remove the tonometer during the course of equilibration and subsequent reading. The accuracy of the method has been increased thereby. The manner of holding tonometers is shown in figure 1. After equilibration a beam of light can be projected through the hemoglobin solution within the

tonometer to the spectro-comparator where comparisons can be made with standard solutions.

A copper jacketed water bath was constructed with a brass collar (*B*) in which a brass holder (*A*) can be rotated. A tonometer is placed into (*A*) and shaken through a 20-30 degree angle from the horizontal plane so that a solution will flow from one end of the tonometer to the other. After ten minutes of shaking the tonometer is brought into a vertical

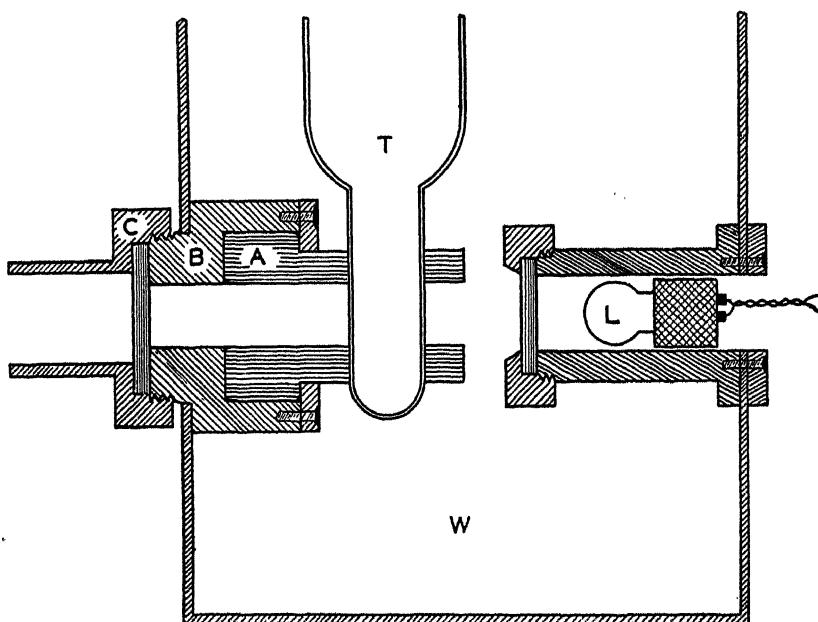


FIG. 1. Shows the position of a tonometer in the water bath (*W*). The holder (*A*) for the tonometer (*T*) rotates in (*B*). Two glass discs are shown, one between (*C*) and (*B*) and one in front of light (*L*).

position and the solution flows into the test-tube like end, through which the beam of light from (*L*) passes. A brass collar (*C*) was constructed to fit into the end of the spectroscopic eyepiece. A glass disc such as is used in colorimeter cups is held between (*C*) and (*B*).

A brass tube (*D*) with a frosted glass disc contains a 6 volt mazda bulb (*L*). The intensity of illumination from (*L*) and from the light on the colorimeter is controlled from resistances near the colorimeters. A resistance box is shown beneath the colorimeter in plate 61.

## TONOMETERS

A photograph of a tonometer is shown in plate 61. The end which was inserted into holder (*A*) was similar to a test-tube and about 15 millimeters in diameter. The inside diameter should be known. The aperture in (*A*) and (*B*) through which light passes to the spectro-comparator was 10 millimeters in diameter. Consequently, knowing the inside diameter of the tonometer one can calculate the average depth of solution for an area of cross section of a beam of light of 10 millimeters. This should be taken into consideration in making proper dilution of standards for the colorimeter cups. When that is done the standard solutions will yield a comparable spectrum to that in the tonometer.

TABLE 1

SHOWING A COMPARISON OF SPECTROSCOPIC AND VAN SLYKE ANALYSES ON SHEEP'S HEMOGLOBIN AT VARIOUS OXYGEN TENSIONS IN PHOSPHATE BUFFER, pH 6.8

PARTIAL PRESSURE OF OXYGEN <i>mm. Hg</i>	PERCENTAGE SATURATION WITH OXYGEN	
	Spectroscopic	Van Slyke
19	13	14
31	29	31
40	45	43
52	61	59
60	69	67
65	61	60
71	74	72

A total capacity of about 60 cc., when 5 cc. of hemoglobin solution is used, has been found to be a satisfactory one for tonometers.

## PROCEDURE

Samples of blood are hemolysed in 10 volumes of distilled water and centrifuged for 2 or 3 minutes. Five cubic centimeters of the hemolysed solution is added to 45 cc. of an appropriate buffer solution. If blood of low oxygen capacity is used it may be necessary to use a smaller dilution. In order to get best results one should attempt to obtain a dilution which will give the most distinct absorption bands.

If the depth of solutions in the colorimeter cups is made equal to the average depth of solution in the tonometer through which the light traverses, the spectra should be identical. A more convenient manner

of reading and simplifying calculations of results is to set the depth of solutions in the colorimeter at 20 millimeters and to further dilute the standards to the extent that their hemoglobin concentration multiplied by 20 is equal to the hemoglobin concentration in the tonometer multiplied by the average depth of the solution (in millimeters), then the two spectra will be identical.

Calculations of oxygen tensions are made as previously described.

The results of a comparison of determinations made on purified hemoglobin with a Van Slyke manometer apparatus and the spectro-comparator are shown in Table 1. Great care was taken to prevent formation of methemoglobin. It will be seen that the spectro-comparator yields results fairly similar to that of the Van Slyke apparatus.

The spectroscopic method is limited to percentage saturations between 20 and 80 and it requires some practice in matching the spectra. Thus there is introduced a subjective error. Its chief advantages are simplicity and economy of samples. It is particularly useful where hemoglobin is to be studied in dilute solutions.

#### SUMMARY

Improvements on a spectroscopic method are described whereby dissociation curves of hemoglobin can be made.

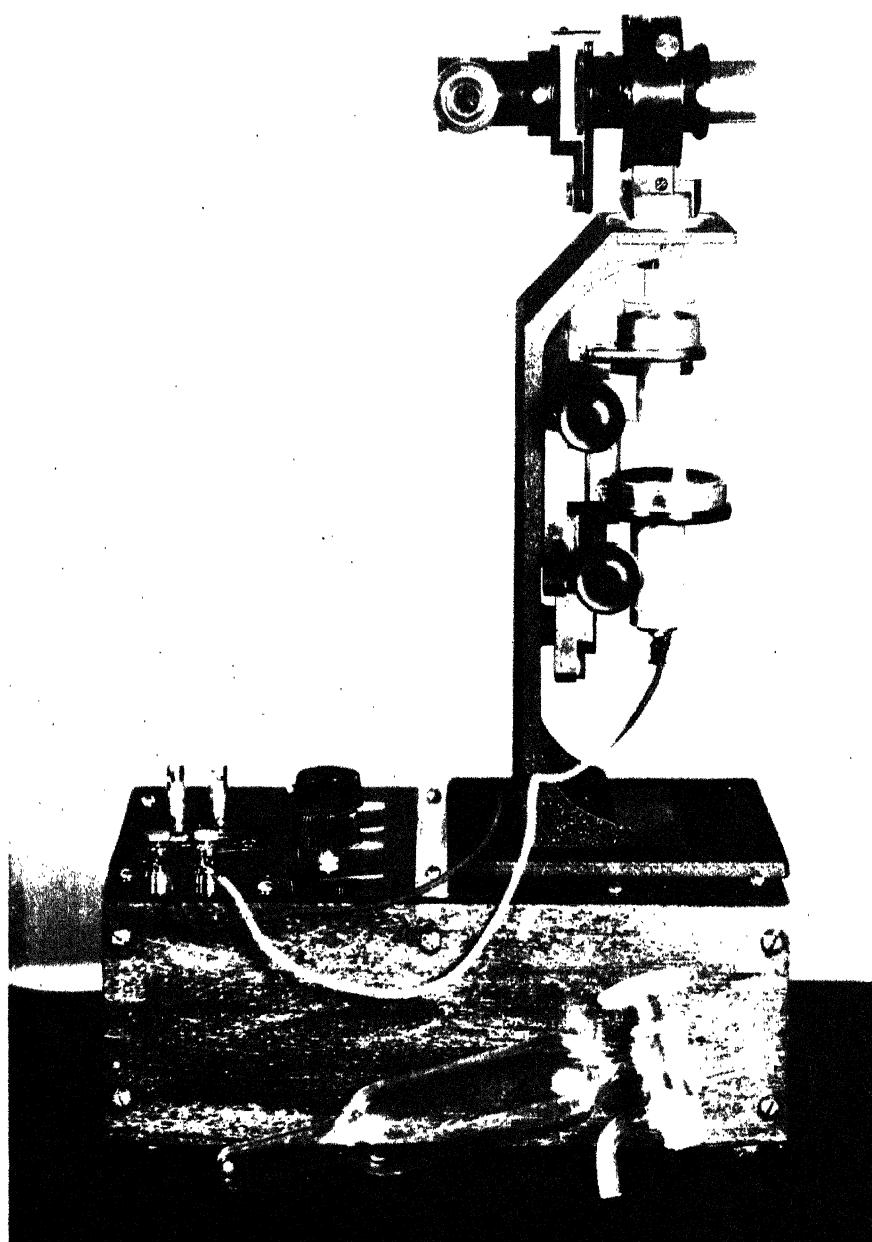
ZOOLOGY DEPARTMENT,  
DUKE UNIVERSITY,  
DURHAM, N. C.

#### PLATE 61

PHOTOGRAPH OF SPECTRO-COMPARATOR SHOWING POSITION OF THE SPECTROSCOPIC EYEPIECE

A resistance box and tonometer is shown beneath the colorimeter

PLATE 61





## AN INCOMPLETELY KNOWN CHYTRID: MITOCHYTRIDIUM RAMOSUM

By JOHN N. COUCH

### PLATE 62

The genus *Mitochytridium* was established by Dangeard in 1911 for a Chytridiacean fungus which he found attacking desmids of the species *Docidium Ehrenbergii* and named *M. ramosum*. By the structure and arrangement of the rhizoidal system this parasite showed a resemblance to *Catenaria anguillulae* but differed from that in the absence of cross walls in the part of the thallus which gives rise to spores. There is also a resemblance to *Lagenidium* and *Myzocytium* but these two latter genera lack rhizoids and the thallus, when well developed, is separated into several or many distinct sporangia. Dangeard was of the opinion that this parasite was intermediate between the Chytridiaceae and the Acanthocystidaceae.

Butler (1928) was of the opinion that the fungus should be put in the Cladochytriaceae close to *Catenaria*. Fitzpatrick (1930) placed the genus in the doubtful or excluded Acanthocystidales because of Dangeard's rather inadequate discussion of its relationship.

Up to the present time the fungus has not been reported since Dangeard's original description. I found the species growing abundantly May 19, 1933, in *Docidium Ehrenbergii* and other species of desmids collected from near Wilmington, N. C., April 23, 1933. Because of the abundance of material, it was possible to work out most of the details in the life history of the parasite, and since the position of the fungus was doubtful it seemed worthwhile to record these observations. The original description of Dangeard is complete in most details and hence I was able to add but little to his observations. The most important additional observation was that the wall membrane gives a pale purplish color with chloriodide of zinc thus indicating its cellulose composition and its similarity to the cell walls of the Acanthocystidales rather than to the Chytridiales.

#### DEVELOPMENT OF THE FUNGUS

A spore of the parasite comes to rest on the host, loses its cilium and sends through the host wall a thin tube. The tube may enlarge into the

thallus of the parasite immediately upon penetration or it may grow for some distance before enlarging. Only in a few cases have I been able to detect the old empty spore membrane. The thallus as a rule becomes detached from the empty spore membrane. The thallus grows, becoming  $10\text{--}13\mu$  thick and sometimes extending for the entire length of a *Docidium* cell (about  $660\mu$  long). Usually, however, the thallus is shorter. Sometimes the individual parasites may be nearly straight and unbranched, more frequently, however, the thallus is twisted and branched. As a rule the fungus is of more or less the same thickness throughout its length though not rarely one notices places in the thallus up to  $20\mu$  thick. The rhizoid is usually single, i.e., it extends out from the body of the parasite as a single thread which quickly branches out into a number of fine threads. The rhizoids are fairly conspicuous on young plants but as the plant matures they become more or less empty so that they are rather difficult to see except under high magnification ( $\times 1,000$  or more).

The protoplasm has the pale whitish gleam and the fat globules characteristic of the Chytridiales. The development of the sporangium appears to be the same as in *Rhizophidium globosum*.

Just before the maturing of the spores a narrow emergence tube grows out through the wall of the desmid (fig. 6) and through this the mature spores are discharged (fig. 9). The spores emerge with their cilia directed backwards and swim away immediately upon reaching the exit. The spores swim as is characteristic for the chytrid spore such as *Rhizophidium*, darting here and there with the cilium behind.

In the same desmid with the sporangia several or many spherical or somewhat elongated thick-walled resting bodies may be formed. These vary from  $12\text{--}18\mu$  thick. It appears that several resting bodies may be formed from a single spore (fig. 8). During the development of the resting body it is equipped with rhizoids which disappear leaving a few spines or blunt protuberances. Germination of these bodies has not been observed. The fact that they give a cellulose reaction with chloriodide of zinc as do the sporangial walls and are rather constantly associated with the sporangia is good evidence that the resting sporangia belong to the same fungus.

It appears to me that this fungus is closer to the Chytridiales than to the Acyclistales for the following reasons: (1) the presence of rhizoids, and (2) the development, structure, and mode of swimming of the zoospores which are as in typical chytrids. The resemblance to *Lagenidium* in the shape of the thallus (except for the rhizoids in the

present plant) and in the cellulose wall is striking but the characters mentioned above relating the fungus to the Chytridiales would seem to be of more fundamental importance.

This fungus seems to belong in the Cladochytriaceae as already suggested by Butler (1928). It is interesting to note that Dangeard himself considered the fungus a chytrid as his title indicated. The present fungus differs from *Catenaria* in that in the latter the thallus usually becomes segmented into several sporangia connected by narrow isthmuses, whereas in the present fungus the thallus gives rise to only one sporangium. It appears however, that in *Mitochytrium* one thallus may give rise to several resting sporangia (fig. 9). It is true as pointed out by Butler (1928) that in *Catenaria* the thallus may sometimes become a single sporangium.

If the cell wall of *Catenaria* should turn out to be cellulose that would indicate a further relationship between that fungus and *Mitochytridium*.

The present fungus may easily be distinguished from *Endochytrium* or *Megachytrium*, two new genera recently described by Sparrow (1933), since in both of these genera the sporangia open by the pushing aside of a distinct operculum.

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## EXPLANATION OF PLATE 62

## MITOCHYTRIDIUM RAMOSUM DANGEARD

Fig. 1. Habit of fungus in cell of *Docidium* sp. Also parasitic on the same desmid is a species of *Phlyctochytrium* and *Rhizophidium*.  $\times 262$ .

Figs. 2-4. Early stages in development of sporangia. Figure 4 shows rhizoids still continuous with sporangium. Figures 2 and 3  $\times 840$ , figure 4  $\times 938$ .

Figs. 5, 6. Later stages in development of sporangia and spores. Figure 5 shows how the tiny globules of fatty (?) material collect to form a single large globule for each spore. In figure 6 the rhizoids are separated from the sporangia by septa. Figure 5  $\times 840$ , figure 6  $\times 938$ .

Fig. 7. A small sporangium with infecting cell still evident.  $\times 1120$ .

Fig. 8. Part of a desmid containing several large sporangia one with spores about ready to emerge and the others with spores emerging.

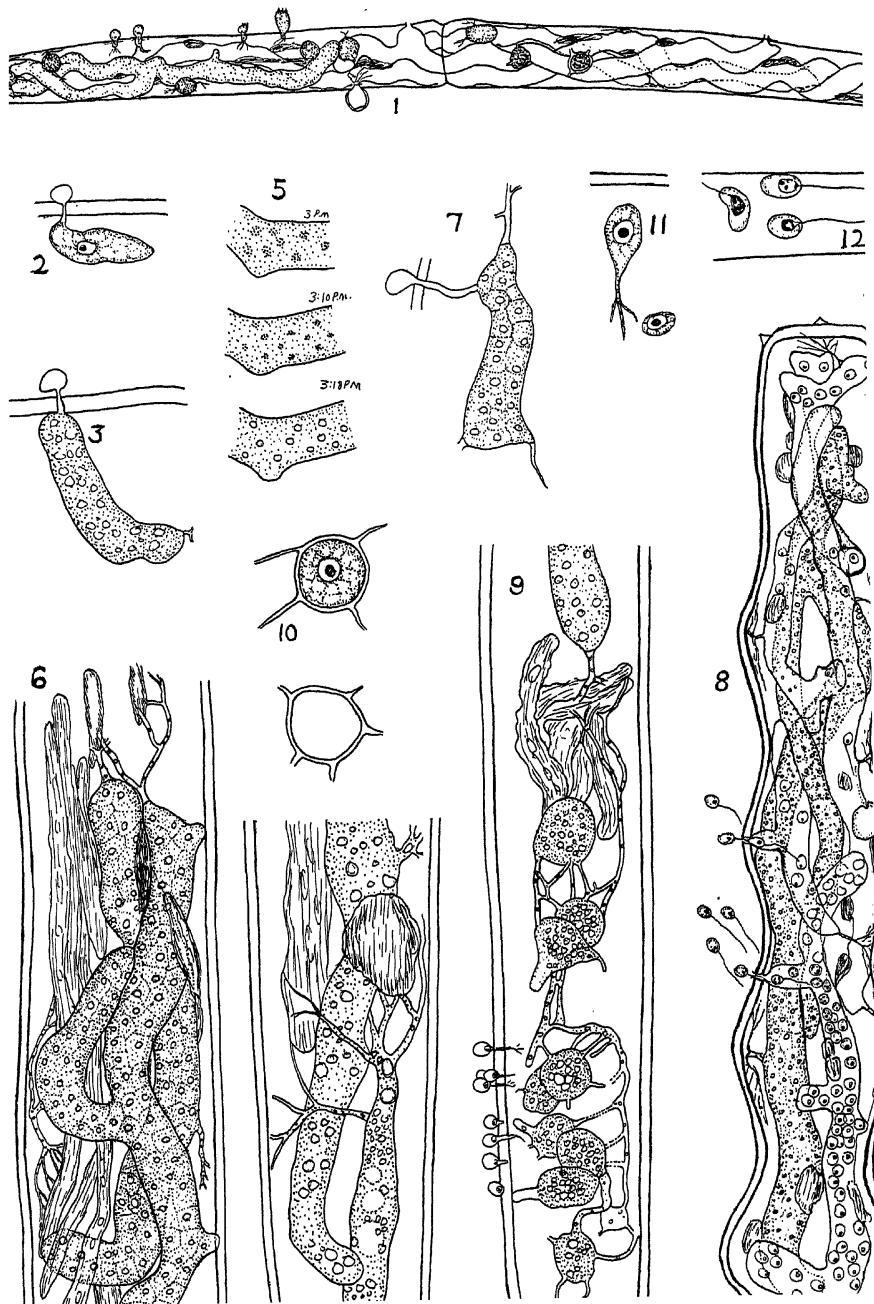
Fig. 9. Several resting bodies connected by narrow threads. As the resting bodies mature these connections are broken.  $\times 840$ .

Fig. 10. Mature resting bodies, one showing nucleus.  $\times 938$ .

Fig. 11. Young thalli, one before and the other after rhizoids have begun to develop.  $\times 938$ .

Fig. 12. Spores killed in sporangium and stained with iron alum haematoxylin, showing cilia and nuclei.  $\times 1425$ .

PLATE 62





A STUDY OF THE CAVE SPIDER, *NESTICUS PALLIDUS*  
EMERTON, TO DETERMINE WHETHER IT BREEDS  
SEASONALLY OR OTHERWISE

By J. D. IVES

The study was made at Three Springs Cave (Buttry's Cave, Delaps Cave), Tennessee. The spiders were studied in a secluded chamber 800 feet from the main entrance. As in the deep interior of other caves, the temperature, relative humidity and light remain practically constant throughout the year. The recorded temperatures range between 58° and 60°F. The relative humidity being above 80 per cent (Jour. of the Elisha Mitchell Sc. Soc., Vol. 43, Nos. 1 and 2, December, 1927, page 86). The evaporating power of the air was only 0.004476 cc. per hour between 4:40 P.M., October 25, 1928, and 6:20 A.M., November 10, 1928.

The animals that have been found in this inner chamber are one salamander, *Gyrinophylus danielsi*, numerous individuals of the milliped, *Cambala annulata* Say, a number of individuals of the rove beetle *Echochara lucifuga* (*Rheochara lucifuga* Casey), a number of individuals of the fungus gnat, *Sciara* sp. and six specimens of *Prionochaeta opaca* Say (determined by W. S. Fisher of the U. S. National Museum). Mr. Fisher states that this beetle is a normal surface form, living in animal and bird nests. There is a deep sink hole not very far from this region of the cave and probably this beetle obtained entrance through some small passages from there. The beetles were caught in a trap of meat bait and Galt's solution (H. S. Barber, Jour. Elisha Mitchell Sc. Soc., June, 1931, Vol. 46, No. 2, pp. 259-265).

From January, 1933, through September, 1933, a record was made each month of those spiders which were carrying cocoons. The carrying of a cocoon was the criterion used to determine the breeding of the spider, *Nesticus pallidus* Emerton. Some spiders were found which were carrying egg cases all during this period. However during this period a very limited space was observed, but the results were interesting enough to attempt a more extended study to determine if *Nesticus pallidus* Emerton bred seasonally or if it did so more or less throughout the year, since temperature, light and relative humidity remain practically constant, as already indicated. It was therefore decided to study a

larger area. There was included in the larger area a mound of bat guano, 6 or 7 feet in extent and 2 or 3 feet high. The walls of the cave next to the mound were also included but not the top of the chamber which was too high for accurate observation. Each time counts were made they were confined to this area, and were limited to the large adult spiders, though a very few not fully mature spiders may have

TABLE 1

COUNTS MADE OF *NESTICUS PALLIDUS* EMERTON, WITH A COCOON ATTACHED, WITHOUT A COCOON ATTACHED AND THE TOTAL NUMBER OF SPIDERS COUNTED, AT 800 FEET FROM THE ENTRANCE OF THREE SPRINGS CAVE, 10 MILES FROM MORRISTOWN, TENN.

TIME	SPIDERS WITH COCOONS	SPIDERS WITHOUT COCOONS	TOTAL NUMBER OF SPIDERS COUNTED
<i>1933</i>			
Oct. 12	26	42	68
Nov. 14	19	47	66
Dec. 12	14	47	61
<i>1934</i>			
Jan. 13	24	47	71
Feb. 10	25	61	86
Mar. 14	34	36	70
Apr. 16	45	39	84
May 16	17	56	73
June 18	23	63	86
July 23	12	50	62
Aug. 21	10	60	70
Sept. 18	20	45	65
Oct. 15	50	49	99
Nov. 15	14	62	76
Dec. 14	21	45	66
<i>1935</i>			
Jan. 14	19	47	66
Feb. 13	26	47	73
Mar. 14	28	60	88
Apr. 16	28	54	82

been counted a few times. Only those cocoons were counted that were being carried by the mother spider. The results of the study are given in table 1 and are represented in graphic form by figure 1.

The table and figure show that breeding occurred throughout the year and that there occurred two times of more than usual breeding activity during the period studied. One time of excessive cocoon formation occurred in April and the other in October of 1934. The April large production of cocoons is rather remarkable in that it corre-

sponds very well with the general breeding season outside the cave. A theory as to the excessive breeding periods, as observed in the cave with reference to *Nesticus pallidus* Emerton, was made after a careful study of the notes of the expeditions, but more data are desired and are being collected to test the verity of the theory. However the data already obtained prove that *Nesticus pallidus* Emerton does breed both

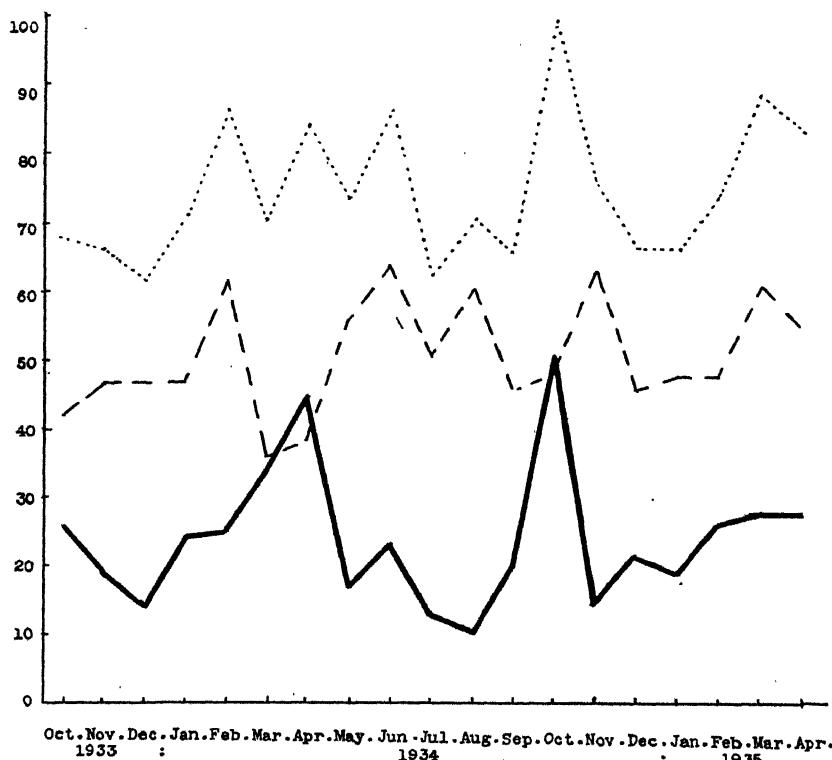


FIG. 1. The ordinates represent the number of spiders observed. The abscissae indicate the date of observation. —— spiders carrying cocoons. - - - spiders without cocoons. .... total number of spiders counted.

winter and summer throughout the year as indicated for the period between October 12, 1933, and April 16, 1935, regardless of whether there is a breeding season outside of the cave or not, since at least some spiders were found with cocoons at all times during that period.

## CHANGE OF RESILIENCY WITH THE VELOCITY OF IMPACT

By J. B. DERIEUX

When a body is suddenly distorted and suddenly released, the average external force exerted by it in returning to its original shape is less than that which is required to distort it. A standard method of demonstrating it, and measuring the relative values, is the method of letting the body fall from a measured height onto a rigid, immovable surface which is horizontal, and observing the height of rebound. The height of rebound is always less than the height of fall. If the forces were equal, the heights would be equal.

The velocity of impact and the velocity of rebound can be computed from their respective heights. The ratio of the latter, or restored velocity, to the former, or destroyed velocity, is called the Coefficient of Restitution, i.e., its value is the coefficient by which the destroyed velocity must be multiplied to find the restored velocity. Expressed in mathematical terms,

$$k = v_1/v, \text{ or } v_1 = kv,$$

where  $v$  and  $v_1$  are the velocity of impact and velocity, of rebound respectively, and  $k$  is the coefficient.

The ratio of the total change in velocity, including sign, to the velocity of impact is called the Resiliency. Mathematically, again,

$$R = (v + v_1)/v, \text{ or } R = 1 + v_1/v = 1 + k.$$

Therefore, in determining the resiliency of a body the method is to measure its coefficient of restitution, and add unity to it.

The published values of the Resiliency of bodies give only one value for each, thus indicating that it is a constant. I had suspected that it might not be constant, but might vary with the velocity of impact, and, hence, the present problem was undertaken. Golf balls were selected as suitable bodies with which to make the study. The range in velocities was obtained by dropping them, in addition to the usual laboratory height, from the first, second, and third floors and the roof of the physics building of State College onto the stone steps. The heights of rebound were determined by an observer stationed on a slight elevation at a little

distance from the building, and who noted the points on the building to which the balls rebounded.

As previously indicated, the Coefficient of Restitution was first computed, and then the Resiliency was taken as that plus unity. It was realized that the resistance of the air had a considerable effect on the high velocities used, and, therefore, the velocities were computed by the following line of reasoning. *Considering first that of the Fall*, the kinetic energy at impact must equal the work of gravity during the fall, diminished by the work of the resistance of the air. Or

$$wv^2/2g = wh - W_r,$$

where  $w$  is the weight of the ball,  $v$ , its velocity at impact,  $g$ , the acceleration of gravity, and  $W_r$  is the work of the air resistance. Solving,

$$v = \sqrt{2gh - 2W_r g/w} \quad (1)$$

For the work of the air resistance,

$$W_r = \int_0^h r dy \quad (2)$$

Here  $r$  is the resistance,  $dy$ , the increment of fall, and  $h$  is the total height of fall. Substituting the value of the resistance, obtained from a previous piece of research which I had done,

$$W_r = 2.62 \times 10^{-5} \int_0^h v^{1.63} dy \quad (3)$$

To convert to a single variable, use was made of the simple vacuum relation,

$$v = (2gy)^{\frac{1}{2}},$$

which, while it is only approximately correct due to the air resistance, is only a correction term, and gives a maximum error of less than 1 per cent in the final result, for the values of  $v$  which I used, which is as close as I claim for my observations. The exact method, which is far more complicated, leading into an infinite series, but which must be used with higher velocities or for closer accuracy, will be given at the close of the paper. Substituting in (3),

$$W_r = 2.62 \times 10^{-5} \int_0^h (2gy)^{.82} dy = 2.62 \times 10^{-5} \times \frac{(2gh)^{1.82}}{1.82 \times 2g}.$$

Substituting in (1),

$$v = \sqrt{2gh - \frac{2.62 \times 10^{-5} (2gh)^{.82}}{1.82 w}}.$$

Substituting the values of  $g$  and  $w$ ,

$$v = \sqrt{2gh} \sqrt{1 - \frac{2.62 \times 10^{-5} (64.4)^{.82}}{1.82 \times 0.1} h^{.82}}.$$

Finally,

$$v = \sqrt{2gh} \sqrt{1 - 4.35 \times 10^{-3} h^{.82}}.$$

The  $\sqrt{2gh}$  is the usual expression for the velocity of fall where there is no resistance, which, if you please, I should like to call the apparent velocity, and the other radical, I should like to call the correction factor.

The preceding expression, as I mentioned, is for the velocity of Fall. In the Rebound, the resistance of the air aids gravity, and the initial expression is

$$wv_1^2/2g = wh_1 + W_r.$$

The final result for it is

$$v_1 = \sqrt{2gh} \sqrt{1 + 4.35 \times 10^{-3} h_1^{.82}}.$$

The Coefficient of Restitution,

$$k = v_1/v = \frac{\sqrt{2gh_1} \sqrt{1 + 4.35 \times 10^{-3} h_1^{.82}}}{\sqrt{2gh} \sqrt{1 - 4.35 \times 10^{-3} h^{.82}}}.$$

The ratio of the first two radicals reduces to  $\sqrt{h_1/h}$ , which is the usual form without resistance, and which I shall call the apparent coefficient and, therefore, I shall call the ratio of the second two radicals the correction factor.

You can see from the values in the table that my suspicion as to the lack of constancy of the coefficient of restitution and of the resiliency, as the velocity changes, is rewarded. The former shows a decrease of 5.5 per cent, and the latter a decrease of 2.5 per cent as the velocity increases, in the small range which I used. Therefore, as a means of standardizing, I suggest that when the value of the coefficient of restitution or the resiliency for a body of material be given, that it be the value for zero

velocity, as is similarly done for other phenomena which vary with their conditions. This reduction to zero value may be made by formula or graph as described in my next paragraph.

The graph obtained of the Coefficient of Restitution against velocity is a nice smooth curve. To determine how the coefficient changes in

TABLE 1

HEIGHT		APPARENT VELOCITY		VELOCITY CORRECTION FACTOR		CORRECTED VELOCITY		APPARENT COEFFI- CIENT	COEFFICIENT COR- RECTION FACTOR	CORRECTED COEFFI- CIENT OF RESTITU- TION	RESILIENCY
Fall	Rise	Impact	Rebound	Impact	Rebound	Impact	Rebound				
ft.	ft.	ft./sec.	ft./sec.	ft./sec.	ft./sec.	ft./sec.	ft./sec.				
0.0*	0.0	0.0	0.0	1.00	1.000	0.0	0.0	.836	1.00	.836	1.836
3.00	2.05	13.9	11.5	.995	1.004	13.8	11.55	.826	1.009	.835	1.835
16.33	10.30	32.4	25.7	.978	1.013	31.7	26.00	.794	1.038	.824	1.824
29.00	17.00	43.3	33.1	.965	1.023	41.8	33.98	.767	1.062	.814	1.814
47.50	25.58	55.3	40.6	.947	1.032	52.3	42.01	.734	1.091	.800	1.800
60.00	30.70	62.2	44.5	.935	1.036	58.1	46.1	.715	1.107	.790	1.790

\* This line of data was determined from a graph, as described in the paper.

relation to the velocity, an exponential relation was assumed and the equation

$$k = c - c_1 v^n$$

solved by substituting values of  $k$  and of  $v$  from the data. The solution is

$$k = .836 - 5.71 \times 10^{-6} v^{2.21}.$$

A graph between coefficient and  $(\text{velocity})^{2.21}$  is linear, thus verifying the solution. After getting the linear graph, its prolongation until it cuts the axis of coefficients gives, of course, the value of the coefficient for zero velocity, which is .836. The general equation is

$$k_v = k_o - 5.71 \times 10^{-6} v^{2.21},$$

or

$$k_o = k_v + 5.71 \times 10^{-6} v^{2.21},$$

where  $k_v$  and  $k_o$  are the coefficients at velocities  $v$  and  $o$ , respectively. The latter form serves for finding the value at zero velocity. For the equation of Resiliency, adding unity to the coefficient,

$$k_v + 1 = k_o + 1 - 5.71 \times 10^{-6}v^{2.21},$$

or

$$R_v = R_o - 5.71 \times 10^{-6}v^{2.21},$$

and

$$R_o = R_v + 5.71 \times 10^{-6}v^{2.21},$$

where  $R_v$  and  $R_o$  are the resiliences for velocities  $v$  and  $o$ , respectively.

Several other interesting graphs and relations were obtained from the results. Taking them in the order in which they appear in the table, there are two for the Velocity Correction Factors, as ordinates, in relation to Height. The graph for the fall is inclined downward but is concave upward, while the one for the rebound rises but is convex upward. The equations for them are

$$Cf = \sqrt{1 - 4.35 \times 10^{-3}h^{.82}},$$

and

$$Cr = \sqrt{1 + 4.35 \times 10^{-3}h^{.82}},$$

respectively, as is shown in the previous method of analysis. Then there is one for the Initial Velocity of recession, and Height of Rebound as abscissa. The graph rises and is convex upward. The equation is

$$v_i = \sqrt{2gh} \sqrt{1 - 4.35 \times 10^{-3}h^{.82}}.$$

The graph for the Final Velocity, and Height of Fall as abscissa, rises but is convex upward, and more convex than the one for rebound. It was extended by the infinite series method mentioned previously, and given later, and the velocity was found to reach its maximum value of 158 feet per second in a fall of about 2000 feet, the graph becoming horizontal.<sup>1</sup> An application of this to the case of a golf ball dropped from an aeroplane is interesting. When first dropped, its velocity would increase at the rate of 32.2 feet per second, but this rate would decrease, due to the resistance of the air, and when it had fallen about 2000 feet its velocity would be constant, at 158 feet per second. Another graph and relation is the Height of Fall, abscissa, against Restitu-

<sup>1</sup> See page 207 of this issue.

tion Correction Factor. This rises and is convex upward. The equation for it is

$$Cf = 1.00 + 4.67 \times 10^{-3}h^{.7}.$$

Now, for the more exact equation of motion. For unit of mass,

$$dv/dt = g - cv^n,$$

where  $g$  is the acceleration of gravity,  $c$  is a constant,  $v$ , the velocity, and  $n$  the exponential rate of change of resistance with velocity. If  $V$  represent the limiting velocity attainable in falling, due to resistance, then

$$0 = g - cV^n \quad \text{or} \quad c = g/V^n.$$

Substituting,

$$\frac{dv}{dt} = g - g \frac{v^n}{V^n} \quad \text{or} \quad \frac{vdv}{dh} = g \left( 1 - \frac{v^n}{V^n} \right),$$

whence

$$gdh = \frac{vdv}{1 - \frac{v^n}{V^n}} = v \left[ 1 - \left( \frac{v}{V} \right)^n + \left( \frac{v}{V} \right)^{2n} + \dots \right]$$

Integrating,

$$gh + C = v^2 \left[ \frac{1}{2} - \frac{1}{n+2} \left( \frac{v}{V} \right)^n + \frac{1}{2n+2} \left( \frac{v}{V} \right)^{2n} + \dots \right]$$

If the body falls from rest,  $h = 0$  when  $v = 0$ , and, therefore,  $C = 0$ . By substituting a series of values for  $v$ ,  $V$  having previously been determined to be 158 feet per second, and solving for  $h$  in each case, a series of values of  $h$  was determined from which a graph between  $h$  and  $v$  was plotted, and from it the value of  $v$  corresponding to any  $h$  was read.

For the Rebound, the initial equation is changed only by a plus sign in the last term, because gravity and resistance then operate in the same direction. This sign change results in changing the final form only by a negative sign before the even numbered terms of the bracket.

NOTES ON SOME OOMYCETES FROM THE VICINITY OF  
MOUNTAIN LAKE, GILES COUNTY, VIRGINIA<sup>1</sup>

By VELMA D. MATTHEWS

PLATE 63

Although some work has been done on the oomycetes of Virginia, published records on the distribution of members of the families Saprolegniaceae, Acanthostomataceae, Leptomitaceae, and Monoblepharidaceae seem to be practically lacking, so far as the writer is aware. Coker (1927) lists *Achlya flagellata* and a sterile form of *Saprolegnia* from Charlottesville, Virginia. Drechsler (1927) reports *Plectospira myriandra* from Rosslyn, Virginia, and the same author (1935) isolated *Aphanomyces cladogamus* from this state. Couch (1935) described *Lagenidium giganteum* from Mountain Lake, Virginia, and Chapel Hill, N. C. During July and August of 1935 the writer noted the occurrence of several genera belonging to the above mentioned families in about sixty collections of water, twigs that had been lying in the water for some time, and soil. These collections were made within three miles of the Mountain Lake Biological Station at elevations ranging from about 3,800 to 4,300 feet. All of the species listed below except two, although they are probably very common in many parts of the state, are reported from Virginia for the first time and a few of them have not previously been reported from the south.

SAPROLEGNIACEAE

*Saprolegnia diclina* Humphrey, Trans. Am. Phil. Soc. 17: 109, pl. 17, figs. 50-53. 1892 (1893).

Growing on a clump of salamander eggs on damp moss. Also very abundant in the water of the lake.

<sup>1</sup> It is a pleasure to acknowledge the many courtesies extended to the writer by Dr. Ivey Lewis, Director of the Mountain Lake Biological Station. The writer is also grateful to Dr. W. C. Coker for suggestions and the use of the University of North Carolina library.

**Saprolegnia litoralis** Coker, The Saprolegniaceae, p. 54, pls. 15, 16. 1923.

Isolated from a small pool of water containing several species of algae, mosquito larvae, and rotifers in a large rock on the top of Bald Knob at an elevation of about 4,300 feet. All previous collections of this species in the United States have been from the coastal plain of North Carolina.

**Isoachlyxa eccentrica** Coker, The Saprolegniaceae, p. 87, pl. 24. 1923.

Isolated twice from soil and once from water: dark sandy soil near *Kalmia* on the grounds of the Biological Station; sandy soil along the path around the lake; collection of water and insect larvae from a small pool in the West Virginia road. Antheridia were lacking in all the collections, but in one collection from soil several sporangia were noted where internal proliferation of sporangia was present. Coker (1923) says that proliferation of sporangia is "never internal as in *Saprolegnia*." Otherwise these cultures agreed with the original description of the species.

**Isoachlyxa unispora** Coker and Couch, The Saprolegniaceae, p. 85, pls. 22, 23. 1923.

Isolated once from dark damp soil near Mud Branch on the Biological Station grounds. Previously reported only from water in the type locality, Chapel Hill, North Carolina.

**Achlya conspicua** Coker, The Saprolegniaceae, p. 131, pls. 45, 46. 1923.

Isolated from a collection of water from the lake containing water mosses and *Isoetes* and from a collection of dark sandy soil near the Biological Station.

**Achlya glomerata** Coker, Mycologia 4: 325, pl. 79. 1912.

Isolated from dark wet soil near *Trautvetteria* and ferns in a low place near the Biological Station. In old cultures a few of the eggs germinated by the formation of a short tube at the tip of which a small sporangium was formed.

**Achlya imperfecta** Coker, The Saprolegniaceae, p. 118, pls. 38, 39. 1923.

Isolated from light gravelly soil in the path around the lake.

**Achlya flagellata** Coker, The Saprolegniaceae, p. 116, pl. 37. 1923.

Growing on an insect larva in a small pool in the West Virginia road. This species was not found in any of the soil collections. In the piedmont section of North Carolina it is found in the soil more often than any other species of the family. The hyphae of the original collection were heavily parasitized by *Pseudolpidium fusiforme* (Cornu) A. Fischer (see fig. 4) and *Olpidiopsis minor* A. Fischer (see fig. 5). The very large sporangia and resting bodies of *P. fusiforme* caused great enlargements of the host hyphae.

**Aplanes Treleaseanus** (Humphrey) Coker, Journ. Eli. Mitch. Sci. Soc. 42: 217, pls. 34, 35. 1927.

Isolated from black damp soil mixed with many hemlock needles from the base of a large hemlock (*T. canadensis*) near the lake. In one culture about three weeks old there were about a hundred typical *Aplanes* sporangia. This collection agreed with the plants obtained by the writer from soil at Lakeview, N. C. (see Coker, 1927).

**Thraustotheca clavata** (de Bary) Humphrey, Trans. Amer. Phil. Soc. 17: 131. 1892 (1893).

Isolated from damp coarse sand near the lake.

**Leptolegnia eccentrica** Coker and Matthews, Journ. Eli. Mitch. Sci. Soc. 42: 215, pl. 33. 1927.

Isolated 13 times from 39 collections of soil. This was the only fungus obtained from collections of soil made in the typical chaparral formation in the vicinity of Bear Cliff at an elevation of about 4,200 feet. Numerous oogonia with mature eggs were formed in cultures on hemp seed that were left in the soil covered with water for a week or more. Cultures on hemp seed in water formed many spores but only a small number of oogonia developed and few of these matured their eggs. This was the most common species of water mold found in the soil in the vicinity of Mountain Lake. Previously this species has been reported only from the type locality, Chapel Hill, North Carolina.

**Dictyuchus monosporus** Leitgeb, Pringsh. Jahrb. wiss. Bot. 7: 357, pl. 22, figs. 1-12 and pl. 23, figs. 1-8. 1870.

Sterile forms were very abundant on many kinds of twigs lying in the lake and in the water of the lake.

**Aphanomyces** sp.

Growing on a mass of frog eggs in the lake. No oogonia were formed so the species was not determined.

## LEPTOMITACEAE

**Gonapodya polymorpha** Thaxter, Bot. Gaz. 20: 481, pl. 31, figs. 11-16. 1895.

Growing attached to birch twigs and inside old hyphae of *Dictyuchus*, which were attached to birch twigs that had been lying in the lake. This species was also found on twigs placed in a wire trap in a spring at Chapel Hill, North Carolina, in 1933. Previously not reported south of New York

**Sapromyces Reinschii** (Schroeter) Fritsch (?), Osterr. Bot. Zeitschr. 43: 420. 1893.

Growing attached to hemlock, birch, and Rhododendron twigs that were lying in the lake. Sporangia borne in clusters of two to twelve. Oogonia lacking.

## MONOBLEPHARIDACEAE

**Monoblepharis polymorpha** Cornu, Bull. Soc. Bot. France 18: 59. 1871; Ann. Sci. Nat. 5 th. ser. 15: 82, pl. 2, f. 1-9. 1872; in Van Tieghem's 'Traité de Botanique' (1874 ed.), fig. 167 B, 4 and fig. 167 C, 7, 1, m, n and 9.

Growing attached to birch twigs lying in the lake. Very rare during July and August but perhaps more abundant in the fall and winter. Previously not reported south of New York.

## ANCYLISTACEAE

**Lagenidium giganteum** Couch, Mycologia 27: 376, figs. 1-19. 1935.

Growing on a mosquito larva in a small pool in a depression of a large rock on the top of Bald Knob at an elevation of about 4,300 feet. Sexual reproduction lacking.

COKER COLLEGE,  
HARTSVILLE, SOUTH CAROLINA.

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### PLATE 63

#### GONAPODYA POLYMORPHA

Fig. 1. Mycelium of fungus forming sporangia inside old hypha of *Dictyuchus* and extending out into the water.  $\times 527$ .

Fig. 2. Proliferation of sporangia.  $\times 527$ .

Fig. 3. Zoospore.  $\times 527$ .

#### PSEUDOLPIDIUM FUSIFORME

Fig. 4. Resting spores inside hypha of *Achlya flagellata*.  $\times 120$ .

#### OLPIDIOPSIS MINOR

Fig. 5. Empty sporangia and resting spores inside hypha of *Achlya flagellata*.  $\times 120$ .

#### SAPROMYCES REINSCHII

Fig. 6. Plant attached to hemlock twig showing habit of growth.  $\times 120$ .

Fig. 7. Young sporangia, one showing spore initials.  $\times 527$ .

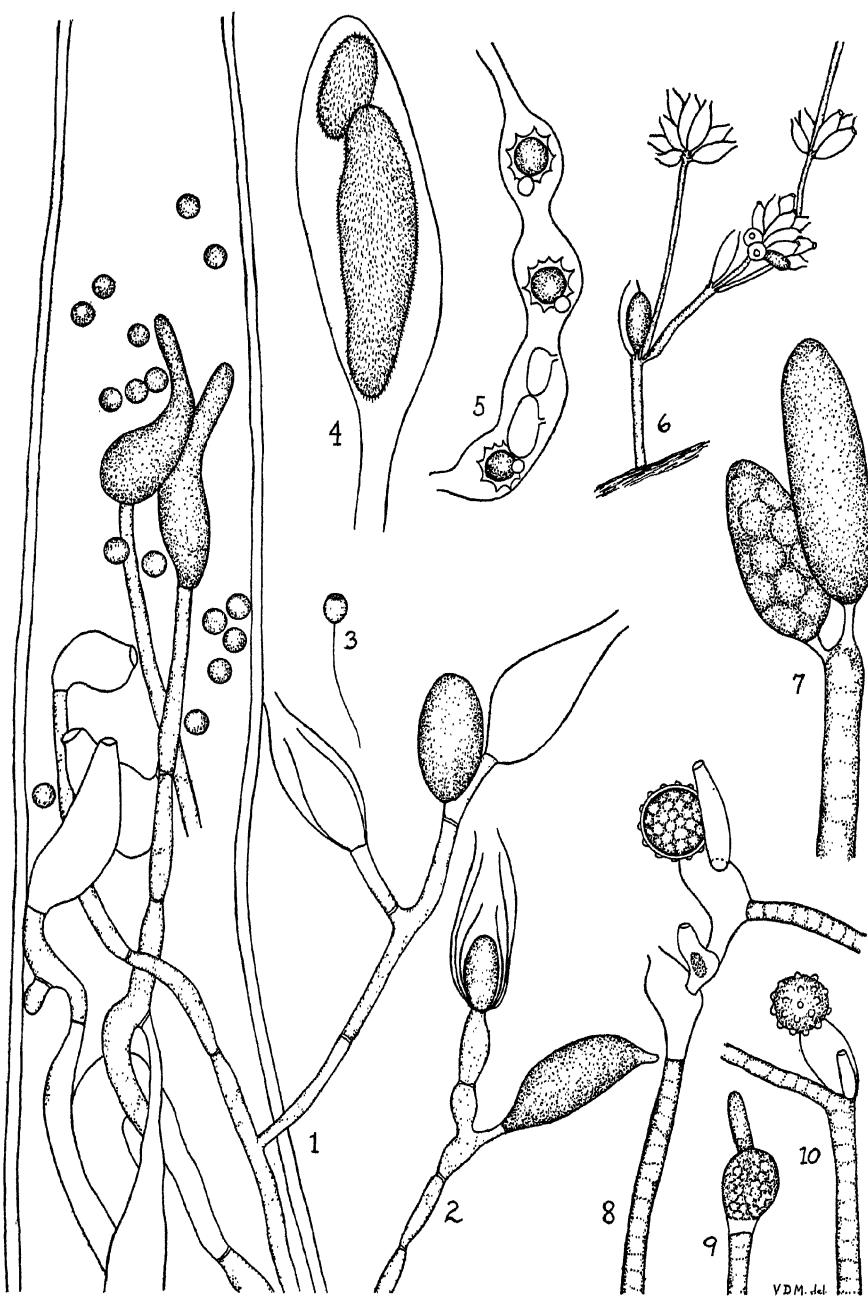
#### MONOBLEPHARIS POLYMORPHA

Fig. 8. Hypha with antheridia and oogonia.  $\times 527$ .

Fig. 9. Young oogonium with an antheridium.  $\times 527$ .

Fig. 10. Surface view of oospore after emergence from the oogonium.  $\times 527$ .

PLATE 63





## BASKING SHARK (*CETORHINUS MAXIMUS*) IN NORTH CAROLINA WATERS

By H. H. BRIMLEY

On February 12, 1935, a female specimen of Basking Shark (*Cetorhinus maximus*) was taken in a shad net about two miles outside Corn-cake Inlet, this being a small channel connecting the Cape Fear River with the ocean a few miles below Fort Fisher.

The specimen measured 13 feet, 5 inches from tip of snout to tip of tail, with a maximum body circumference of 53 inches, and its weight was about six hundred pounds. The gape was 18 inches in width and the caudal fin measured 41 inches from tip to tip.

One of the most striking features of this species of shark is the enormous size of the gill openings, which very nearly meet on both the upper and under sides of the head.

The liver of our specimen measured 61 inches in length and weighed 65 pounds—mostly oil!

The teeth are numerous, recurved, and very small, with no cutting edges, the exposed part of the longest tooth being only about one sixteenth of an inch in length. The gill-rakers are highly developed and are used much as are the whalebone plates in the baleen whales, for straining from the water that flows into the mouth the small forms of marine life on which the animal feeds.

The Basking Shark is an inhabitant of northern seas, and I know of no specimen having been previously taken south of Sea Girt, New Jersey, which is about 430 miles to the north of Corncake Inlet.

The Museum received the specimen in the flesh and, from copious notes, measurements, sketches and plaster moulds, it is intended to later on reproduce the animal as a life-sized model for exhibition.

STATE MUSEUM,  
RALEIGH, N. C.

## THE BIRDS OF CHAPEL HILL, NORTH CAROLINA

By EUGENE ODUM, EDMUND TAYLOR, COIT COKER AND  
ARNOLD BRECKENRIDGE

### PLATE 64

For the past six years we have been greatly interested in the scientific study of the ornithology of the Chapel Hill region, spending considerable time the year round in field work. Associated with us from time to time have been a number of other bird students who have not only contributed many data but have helped to make the study of birds a real pleasure. We wish to mention in this connection the following: Elmer Brown, Freemont Shepherd, Henry Rankin, Claude Rankin, Nelson Hairston, Jim Stephens, Joe Jones, and Gilbert Wagstaff.

We realize that six years is a rather short period in which to make a reasonably complete local list, but we have amassed considerable material which, together with observations of previous students, badly needs consolidation. Also, because of the increasing interest in birds which has been manifested in Chapel Hill in the last few years, we feel that such a publication as this may be helpful to the many bird lovers as well as form a working foundation for future investigations.

*Review of ornithological work.* George F. Atkinson (1854-1918), assistant professor in the "Department of Geology and Natural History" here at the University from 1885 to 1888, was the first to make a scientific study of birds at Chapel Hill. However, he was not primarily interested in local birds but in the distribution of North Carolina birds in general, about which there was little known at the time. In 1887 he published "A Preliminary Catalogue of the Birds of North Carolina, with Notes on Some of the Species" (Jour. E. Mitch. Sci. Soc., IV-2, pp. 44-87). In the introduction to this paper he states that he collected specimens at Chapel Hill from January, 1886, to the time of writing except for the fall and summer of 1886. He further states that 120 species were positively identified, 112 of which were preserved, but he fails to list them.

In 1899, T. Gilbert Pearson (now president emeritus of the National Association of Audubon Societies) compiled "A Preliminary Catalogue of the Birds of Chapel Hill, with Brief Notes on Some of the Species" (Jour. E. Mitch. Sci. Soc., XVI-1, pp. 33-51) embodying the results of

two years (exclusive of summers) of his own studies and the data recorded by Professor Atkinson. He obtained this latter, he states, from a newspaper clipping, "Preliminary List of Birds Collected at Chapel Hill," by Professor Atkinson presumably published about the same time as his North Carolina list. Dr. Pearson's list contains 134 species, 119 of which came under his own observation.

Mr. C. S. Brimley of Raleigh has kindly sent us some scattered notes taken by Mr. G. S. MacNider at Chapel Hill, 1889-1902, which contain authentic records of two additional species, the Wood Ibis and Canada Goose, bringing the total to 136 species.

Alexander Feild in 1912 published a list entitled "Notes on the Birds of Chapel Hill with Particular Reference to their Migration" (Jour. E. Mitch. Sci. Soc., XXVIII-1, pp. 16-33). He lists with notes and some migration data 107 species observed during his four undergraduate years (exclusive of summers). Six species are recorded for the first time, bringing the total recorded number of species to 142.

Aside from these early observers there has been little interest in and very little recorded about local avifauna up until the beginning of our work. The occurrence of only three additional species comes to light, as far as we can determine, two of these being early records apparently not known to Pearson and Feild. These are: Passenger Pigeon (now extinct), one shot in 1887 by Kemp Battle, Jr., Barn Owl taken by T. E. Hester in 1909, and Evening Grosbeak, taken by W. C. Coker in 1922. Thus, at the beginning of our work the "list" was still in an embryonic state totaling 145 species.

Just when our observations began would be hard to say; we have more or less grown up with bird study. Individually we began keeping records about 1928. In 1931 we organized a club and conducted work on a more intensive and concerted scale. Coker and Odum conducted a bird column in the Chapel Hill *Weekly* during 1931 for the purpose of popularizing and stimulating bird study. Detailed records for all seasons have been kept during the four years 1931-34. The greater part of our work has been based on the observation of the living bird in the field, emphasizing occurrence, distribution, and migration; but we have taken for purposes of identification a number of rarer and difficult species. Taylor and Breckenridge have built up small but excellent private collections of bird skins, and we have added some to the University collection. Care and accuracy have been stressed in all field observations. During our study 50 species have been recorded for the first time, making a total of 195 species now known from Chapel

Hill. Many additional data have been added for species already on record. A total of 188 species have actually come under our observation.

*The field.* The territory covered by this list is included within a six-mile radius of the town. It covers, then, the extreme southeast corner of Orange County, a small section of Durham County west to New Hope Creek, and a small area of Chatham County to the south. This area which we shall simply call Chapel Hill has an average elevation of about 500 feet and is located on the eastern edge of the piedmont region of the state in the Upper Austral or Carolinian life zone. Just a few miles to the east, however, at Raleigh, the Lower Austral zone begins to appear. Therefore, birds generally restricted to that region (i.e., the Chuck-will's-widow and the Prothonotary Warbler) might be expected to occur at Chapel Hill at least rarely.

The region is not extensively cultivated and is well-wooded, well-watered, and rather hilly. Much of the natural forest is made up of deciduous trees of the oak-hickory-maple-dogwood association; there are, however, many pure pine stands, and a great deal of mixed wood containing both evergreen and broad-leaved trees. One or two fairly extensive swampy or marshy lowgrounds exist on Bowlin's and New Hope creeks, but no extensive swamps or open marsh lands and no natural ponds of any size are present. Three creeks, Bowlin's, Morgan's, and New Hope, fed by numerous small streams, flow through the Chapel Hill vicinity in a general southeast direction to unite eventually and form a branch of the Cape Fear river.

Ornithologically speaking, Chapel Hill has remained thus from the beginning of bird study until the present time, except for one important change. The construction of two dams in 1932 to form the extensive University Lake just east of town and the much smaller Hogan's Pond to the north, has provided large bodies of water heretofore lacking. Consequently water birds of many species which were previously unknown or were very rarely known to visit our vicinity now are attracted. The status of many, however, is subject to change because of the instability of the lake biologically.

A mention of a few of the places which we have found richest in bird life and which we have most frequently visited should be of interest to future students. Foremost is the strip of remarkably diversified country, known locally as Strowd's lowgrounds, stretching along Bowlin's Creek east of the Durham highway. There is always something interesting to see here even when things are dull elsewhere. The lake and pond mentioned above, together with the surrounding woods and fields,

are, of course, excellent field localities. Morgan's Creek as well as the portion of Bowlin's Creek west of the Durham highway are good, especially in winter and spring. The New Hope swamp off the Raleigh road seems to be very good for spring transient warblers and for some of the wilder birds. The University-owned woods south of the campus and Battle Park are excellent for fall warblers.

*Short review of the seasons; winter.* Birds are by no means scarce in winter at Chapel Hill. In fact, one is likely to see more individual birds on a winter's hike than on one in summer and perhaps as many species, because of the flocking tendencies of birds in winter and because of the great abundance of wintering native sparrows of several species. The seven "Christmas censuses" taken by us and published in *Bird-Lore* magazine from 1928 through 1934 give a pretty good cross-section of the winter bird life. These censuses, which are one day lists, range as follows: 1928, 46 species; 1929, 37 species; 1930, 47 species; 1931, 54 species; 1932, 63 species; 1933, 75 species; and 1934, 68 species; the number of individuals ranging between one thousand and three thousand. The great difference in the number of species does not mean that birds were more abundant in latter years, but simply that we have come to know the country better and know where to locate the less common birds. However, the presence of the lake helped greatly in increasing the list for the past three years. Close to 100 species, exclusive of early and late migrants, have been recorded by us during the winter. Of these we can conservatively state that about 60 are of regular occurrence; that is, if one knows where to look for them he stands a very good chance of finding any or all of about that many on a given day. The occurrence of other species is not so certain; they may be present some years, absent others, or at one time during the winter and not at another; one may be able to find them, but cannot depend on it. Some other species are rare with but one or two winter records.

As to the relative abundance of the commonest winter species the following statistics from the seven censuses is interesting though not conclusive: The White-throated Sparrow and the Slate-colored Junco or Snowbird, polling about the same number of individuals, are easily the most abundant. The White-throat is perhaps the more widely distributed. Red-winged Blackbird (local, but large flocks), Song Sparrow, Goldfinch, Swamp Sparrow, Cardinal, Bluebird, and Field Sparrow follow in respective order. Except for the Red-winged Blackbird and the Bluebird, all these species are members of the Finch and Sparrow family, subsisting mainly on seeds in winter.

*Spring.* Although considerable migratory movement among wintering Robins, Rusty Blackbirds, and others begins in February and early March, we consider the spring migration "officially" opened by the arrival of the early summer Warblers and Vireos during the last two weeks in March. The spring is the richest season in bird life because of the spectacular nature of the spring migration, bringing as it does within a few weeks an onrush of full-plumaged, singing birds, some of which settle down here and start nesting and others which pass on to the north. The last two weeks in March and the first three in April at Chapel Hill find most of the summer residents arriving, every day, almost, bringing a new one. The first individuals to arrive are, as a general rule, the birds which nest here, and not those which nest further north, which pass through later. Also several transient species put in their appearance during these weeks. However, the last two weeks in April and the first half of May is the real transient period when anything, however unexpected, may turn up. During the whole spring the winter resident species are continually leaving for northern nesting grounds, but since they do not announce their departure with such certainty as the summer birds announce their arrival, it is often hard to chart accurately their departure. For complete migration data, however, it is necessary to keep records of this class as much as possible.

The height of the transient period, the last week in April and the first week in May, is the climax to the whole spring migration at Chapel Hill. At this time the largest single day lists of the year are obtainable, because transients, summer residents, winter residents, and permanent residents are present, bringing together a greater variety of species than is possible at any other time of the year. Our largest single day list stands at 101 species recorded on May 5, 1934.

After this climax the spring migration quickly tapers off and "officially" closes with the departure of the last Black-poll Warbler between May 26 and June 1.

*Nesting season.* At this latitude the breeding season is relatively long, including not only the summer months but the spring as well. Many species regularly raise two broods a season, and some three; others, particularly those that start late, raise only one. We have actual breeding records for 73 species at Chapel Hill so far. These are starred in the list. At least 15 additional species undoubtedly breed, with a likelihood of others. Several species are present during the breeding season which probably do not breed here.

The English Sparrow is one of the earliest birds to begin nesting, often

commencing during February or March. We have a record of a Starling nest containing young on Feb. 27, 1932. The Great Horned Owl is said to lay in February, although we have no nesting records here. The latter part of March finds a number of birds beginning nesting operations provided the season is not too late. Carolina Wren, Tufted Titmouse, Carolina Chickadee, Cardinal, Bluebird, and Robin are among those that lay in March or early April. By May the nesting season is in full swing, with almost every species engaged in some phase. June finds the early nesters beginning a second brood, later nesters just getting started with the first. In July the season diminishes, and by the middle of August most species have given up family cares and are undergoing the fall molt. The Goldfinch is an exception: it does not begin to nest until July, and we have a record of an occupied nest on September 4. In the case of summer resident species the breeding individuals and particularly the young of the year frequently leave for the south before the species as a whole departs, individuals from further north taking their places, as has been shown through bird banding.

Songs, so characteristic of our small birds and forming one of their strongest esthetic attractions, should be mentioned in connection with the nesting season. In the South where warm weather and food are more abundant and the breeding season longer many species may be heard for a longer portion of the year than in the north. The song is at its best during the breeding season; some species sing only at this time, but others have a much longer song period. We have not made a special study of song periods, but we can safely say that the Carolina Wren is the only bird which sings the year round here. Its loud cheery song may be heard on any day, regardless of weather conditions. The Titmouse, Cardinal, and the Pine Warbler approach the Wren in length of song period. The Vireos, all of them, are persistent singers through the summer months; the Blue-headed Vireo, which comes nearest to being a resident species, is likely to be heard at any time. Luckily, two of the village's best songsters, the Mockingbird and the Wood Thrush, have long song periods, the latter extending to late summer and the former nearly all the year round. The Brown Thrasher, which ranks with the best, on the other hand rarely sings before the middle of March or after May.

Many winter resident species, although not nesting here, give us some samples of their songs, especially on the approach of spring. The White-throated Sparrow may be heard any warm day during its long stay here (October to May).

*Fall.* The fall migration offers a direct contrast to the spring migration in almost every respect. The spring migration is rapid and overwhelming. It comes quickly to a climax and rapidly to an end. The birds are in full plumage and full song; they are in a hurry to get north and start nesting. The fall migration, on the other hand, is long-drawn-out; there is no climax to speak of. The birds are in their dullest plumages and rarely sing; they are in no hurry to get south, at least during the greater part of the migration period. The southward movement at Chapel Hill begins as early as the middle of July with the return of the first Sandpipers, and continues right up until the cold weather of November.

By reason of its contrasting nature, however, the fall migration is of great significance to one who is becoming acquainted with local birds, a fact which is quite often overlooked by amateur students. Many transients are rare in the spring simply because they pass through a given locality within the space of a few days, while in the fall they tarry longer and are consequently commoner. The reverse is also true, but to a less general extent. Then, also, some few species seem to take different routes for their northward and southward journeys. Therefore, a study of both migrations is necessary in determining the status of a migratory species. The Blackburnian Warbler, for instance, is a rare bird in the spring and would be pronounced a rare species if only the spring migration were taken into consideration; in the fall, however, it is not uncommon for six weeks.

Of course the dull plumages, particularly among warblers and water birds, make identification of many species more difficult in the fall, but with the excellent books now available picturing both spring and fall, adult and immature plumages, the distinguishing characters of fall plumages, with some few exceptions, can be mastered without great difficulty.

Flocking, as in winter, is very characteristic of the fall. Not only birds of the same species but birds of different species, often of widely different habits, gather together in loose companies. The woods about Chapel Hill seem very quiet and absolutely devoid of bird life in September and October. But if one wanders about for a while, he is likely to run into a lot of birds at one time, a fall troop, as we call them; the woods for a short space are alive with birds. Not only migrant species are present, but also permanent resident species, especially Titmice and Chickadees, which seem to have caught some of the migratory spirit, so to speak. It should be pointed out that the birds are not actually

migrating at such a time, because almost all birds migrate at night in extended flights (their calls can often be heard in the darkness as they pass overhead); they are merely feeding and move slowly through the woods, so that one may easily follow a troop indefinitely. Sometimes the troop travels in circles or a series of circles, sometimes just aimlessly.

Flocking is also evident in the fields and on large bodies of water in fall.

*The list.* The following list of the birds of Chapel Hill is constructed along the lines of the usual briefly annotated local list. The nomenclature and sequence is that of the 4th (1931) edition of the American Ornithologists' Union *Check-list*. The common or book names are placed first because they are in more general use among ornithologists and in reality are more stable than the scientific names. In a few instances "local" names, which are in general use in this section of the country, are also included (For example "rain crow" or "red-bird"). Family names are included because the families form convenient groups. Other taxonomic data are unnecessary.

Where a species is divided into two or more recognized sub-species we have listed the appropriate form as given by the *Check-list*. In case two sub-species are listed as occurring through this region (for example, Northern and Southern Flicker), both forms are named but in the absence of specimens are treated as one, since sub-species cannot be distinguished in the field. Unless stated, the naming of sub-species is not based on specimens.

Following the name of the bird comes a brief statement of its status and relative abundance, and if it is a migratory species, our extreme (earliest and latest) dates of its occurrence. If our data do not supplant that of earlier lists or if the status of a species seems to have changed radically, separate mention is made of earlier observations.

Our nesting data are meager, since the study of such, except in a few special cases, has been incidental. Wherever we have them, however, nesting dates are included just to give a rough idea of when the species may be expected to nest.

In addition to the above, we have frequently included single words, phrases, or short sentences on the local habitat, the type of country where one could best look for the particular species.

*Terms used.* In describing the status of a bird the usual terms are used as follows: Permanent resident or resident—found the year around; summer resident (visitor)—here for breeding season but wintering farther south; winter resident (visitor)—wintering here but nesting

farther north; transient—passing through in spring or fall or both; casual visitant—of very irregular or accidental occurrence. Because a species is a “permanent resident” does not necessarily mean that it is not migratory. There may be a considerable shifting of individuals north and south, often involving a change in sub-species, although the species as a whole is always present.

In attempting to give some idea of relative abundance, we have adopted the following terms: Common, fairly common, uncommon, scarce, and rare. These terms should not be taken too literally; birds are such motile creatures, varying in abundance from time to time, so that one may gain different impressions at different times. “Common” and “scarce,” particularly, cover a lot of ground. Also, it should be borne in mind that the terms are relative. “Irregular” and “local” are convenient terms which are also applied. In the case of water birds, for reasons already mentioned, we have refrained from attempting to indicate relative abundance, and have recorded only facts of observation.

*Acknowledgments.* We wish to express our special appreciation to Dr. J. M. Valentine, curator of the recently established University Museum of Natural History, for his encouragement and assistance in our bird work, to Mr. C. S. Brimley of Raleigh who has always had an active interest in our work and has made known to us several old Chapel Hill records which might have otherwise been overlooked, and to Warden John Sykes of University Lake who has taken a real interest in the birds and has helped us keep track of the water birds at the lake.—Eugene P. Odum.

The following list contains 195 named species. The symbol \* indicates breeding record.

#### Family GAVIIDAE. Loons

COMMON LOON. *Gavia immer immer*. Transient visitor. Two specimens recorded by Pearson in 1898 remain the only positive records, but Warden Sykes at University Lake has on several occasions described large birds fitting the description of Loons which he saw in late fall, 1933 and 1934; chiefly coastwise.

#### Family COLYMBIDAE. Grebes

HOLBOELL'S GREBE. *Colymbus griseogenus holboelli*. Like the Loon this species is chiefly a coastwise bird in winter, but it appears to occur inland more rarely. The only record here is a specimen taken by Prof. Atkinson in 1887.

HORNED GREBE. *Colymbus auritus*. Status much as with the preceding two species, but seems to be of more regular occurrence. We have records for November 12, 1931; October 23, 1932; March 26, 1933; and December 23, 1933.

PIED-BILLED GREBE. *Podilymbus podiceps podiceps*. Common transient and winter resident; it is almost a permanent resident, being recorded in every month but May and June (i.e., July 21–April 18), but there are no indications that this species breeds here, chiefly because there are no suitable places at present, though it is possible that it does breed somewhere not far from this locality.

#### Family PHALACROCORACIDAE. Cormorants

DOUBLE-CRESTED CORMORANT. *Phalacrocorax auritus auritus*. Rare transient. Single individuals were seen on May 21 and November 5, 1933, at University Lake (Odum).

#### Family ARDEIDAE. Herons and Bitterns

GREAT BLUE HERON. *Ardea herodias herodias*. Occurs sparingly throughout the year; commonest in late March and April; rare in winter. Not known to breed.

AMERICAN EGRET. *Casmerodius albus egretta*. Post-breeding-season visitor (i.e., after the nesting season is over on the coast, the birds wander inland and northward until driven south again at the approach of fall), July 2–September 25. During Pearson's time this bird was very rare, on the verge of extinction by plume hunters, but now with protection the bird has recovered some of its former numbers. Since the construction of University Lake it has been more or less frequent at Chapel Hill.

SNOWY EGRET. *Egretta thula thula*. Post-breeding-season visitor. Like the preceding, this species was once near extermination; today it is still much less common than the American Egret. Single birds were observed off and on by all of us between July 15 and September 12, 1933. This species is sometimes confused with the white immature birds of the next species.

LITTLE BLUE HERON. *Florida caerulea caerulea*. Common post-breeding-season visitor, June 18–September 30. Most of the individuals which visit us at this season are immature birds in white plumage commonly known as "little white cranes." They form a conspicuous feature of the lake in summer. The species has also been recorded twice in the spring, April 29, 1933, and May 5, 1934.

\*EASTERN GREEN HERON. *Butorides virescens virescens*. Summer resident, April 2–October 4. Eggs June 7.

BLACK-CROWNED NIGHT HERON. *Nycticorax nycticorax hoactli*. Scarce spring transient, March 29–May 5. Also an immature bird either of this species or of a Yellow-crowned Night Heron was seen by Taylor July 6 and 7, 1933.

AMERICAN BITTERN. *Botaurus lentiginosus*. Has been observed throughout the year in every month except June and February, but is mostly a transient. Commonest in spring from March to May, less common in fall, rare in summer (July and August) and winter (December and January). No breeding records.

EASTERN LEAST BITTERN. *Ixobrychus exilis exilis*. Only one record, a bird seen by Odum May 24, 1931.

#### Family CICONIIDAE. Storks and Wood Ibises

WOOD IBIS. *Mycteria americana*. Immature male killed by G. S. MacNider, June 12, 1901, six miles south of town.

#### Family ANATIDAE. Swans, Geese, Ducks, and Allies

CANADA GOOSE. *Branta canadensis canadensis*. Transient. Warren Sykes reported geese from University Lake, fall of 1933. MacNider in his notes records wild geese flying over November 11, 1900. Old residents say they were not infrequent years ago. No recent bird student has seen any here.

COMMON MALLARD. *Anas platyrhynchos platyrhynchos*. Winter resident, November 5–May 7.

COMMON BLACK DUCK. *Anas rubripes tristis*. Winter resident. Usually outnumbers the preceding on the lake in winter.

AMERICAN PINTAIL. *Dafila acuta tzitzioa*. Transient and less common winter resident, November 13–April 2.

BLUE-WINGED TEAL. *Querquedula discors*. Transient. Recorded September 17, 1932, April 17, September 12, 1933, September 19, 1934.

\*WOOD DUCK. *Aix sponsa*. "Summer Duck." Resident in small numbers in suitable places. Breeds; adults with young only a little while out of the nest seen April 16, 1932, and May 7, 1933. In late summer small flocks often frequent the wooded portions of University Lake, but at other seasons they are not usually found on large bodies of open water.

REDHEAD. *Nyroca americana*. One record, March 12, 1933, a single bird observed by Jim Stephens.

RING-NECKED DUCK. *Nyroca collaris*. Winter resident. Closely resembles the Scaup, but with good binoculars at fair range one can easily make out the field marks (Male: white crescentic side mark in front of wing, white ring on bill, and dark back without any white. Female: ring bill and white eye ring).

CANVAS-BACK. *Nyroca valisineria*. Winter resident. In the winter of 1932-33 a small flock was observed continually, but it was rare in 1933-34.

LESSER SCAUP DUCK. *Nyroca affinis*. Winter resident, November 6-April 22. Also a single bird seen June 28, 1932, probably a non-breeding bird. This species seems to be more abundant in migration than the Ring-neck, but the majority of wintering birds seems to be individuals of the latter. The Greater Scaup (*Nyroca marila*), a more coastwise bird, may also occur in the Scaup flocks, but except under unusual conditions the two are not readily distinguishable in the field. Two specimens of scaup taken by Taylor proved to be Lesser Scaup.

AMERICAN GOLDEN-EYE. *Glaucionetta clangula americana*. Transient and winter visitor, March 26, April 2, November 17, and January 6.

BUFFLE-HEAD. *Charitonetta albeola*. One record, a male and two females seen November 17, 1933 (Odum).

RUDDY DUCK. *Erismatura jamaicensis rubida*. Winter resident. Regularly observed 1932-33, rare 1933-34.

HOODED MEGANSER. *Lophodytes cucullatus*. Winter resident, November 5-March 12.

RED-BREASTED MEGANSER. *Mergus serrator*. Winter, December 23, 1933; December 23, 1934; January 2, 1935.

#### Family CATHARTIDAE. American Vultures

\*TURKEY VULTURE. *Cathartes aura septentrionalis*. "Turkey Buzzard." Common permanent resident. Breeds; nest with young in May, 1931.

\*BLACK VULTURE. *Coragyps atratus atratus*. "Carrion Crow." Resident, occurs less regularly than the preceding and usually in small flocks. One breeding record, May 5, 1933 (young in nest).

#### Family ACCIPITRIIDAE. Kites, Hawks, and Allies

SHARP-SHINNED HAWK. *Accipiter velox velox*. Winter resident, September 5-May 15. Uncommon. Perhaps also a rare summer resident and breeder as the May 15 record (specimen taken) and summer records from nearby localities would indicate.

\*COOPER'S HAWK. *Accipiter cooperii*. Resident. Commonest in winter and during the migrations. This and the preceding species, sometimes known as "blue darters," are slim, long-tailed, short-winged, slate-colored, bird-eating hawks, generally our only harmful Hawks. They stand in direct contrast with the three following species of genus *Buteo* which are heavy, long-winged, soaring, rodent-eating, conspicuous Hawks, generally beneficial. Eggs April 29, 1898 (Pearson).

EASTERN RED-TAILED HAWK. *Buteo borealis borealis*. Resident. Most conspicuous in winter. Lowgrounds.

\*NORTHERN RED-SHOULDERED HAWK. *Buteo lineatus lineatus*. Resident. More widely distributed than the Red-tail. Especially noisy in early spring. Young birds in nest April 28.

\*BROAD-WINGED HAWK. *Buteo platypterus platypterus*. Fairly common summer resident, April 7-September 6. Two nesting records: two eggs May 2, 1932; young half grown June 13, 1933. Wooded hill-sides alternating with small meadows or fields.

SOUTHERN BALD EAGLE. *Haliaeetus leucocephalus leucocephalus*. Rare visitant during migrations. Single birds observed by Pearson, March 27, 1898; Valentine, October 15 (about), 1934; and Breckenridge, November 24, 1934.

MARSH HAWK. *Circus hudsonius*. Irregular winter resident, August 19-March 26. The grassy flats and treeless marshes which the Marsh Hawk likes are generally lacking here.

OSPREY. *Pandion haliaetus carolinensis*. "Fish Hawk." Mostly transient. Common from the middle of March to May and from late August to October, but it has been observed at other times of the year: July 7, July 22, and December 23, December 24. Not known to breed.

#### Family FALCONIDAE. Caracaras and Falcons

EASTERN PIGEON HAWK. *Falco columbarius columbarius*. Rare transient. One observed at rest and in flight by Jim Stephens, May 3, 1934.

\*EASTERN SPARROW HAWK. *Falco sparverius sparverius*. Resident. Not common. Pearson recorded it as "moderately common" in 1899 and mentioned that a pair roosted under the eaves of New East building on the campus. Eggs May 1899 (Pearson).

#### Family PERDICIDAE. Partridges and Quails

\*EASTERN BOB-WHITE. *Colinus virginianus virginianus*. Common resident, but fluctuating in numbers from year to year.

## Family PHASIANIDAE. Pheasants

RING-NECKED PHEASANT. *Phasianus colchicus torquatus*. Although not a native species, it is being introduced, but as yet with little success in this region. Dr. R. B. Lloyd, of Carrboro, has released several hundred. We have seen a few in the wild state.

## Family MELEAGRIDIDAE. Turkeys

\*EASTERN TURKEY. *Meleagris gallopavo silvestris*. Resident. Still fairly common.

## Family RALLIDAE. Rails, Gallinules, and Coots

KING RAIL. *Rallus elegans elegans*. Winter resident. Very secretive, but often noisy. Marshy, reedy places.

VIRGINIA RAIL. *Rallus limicola limicola*. Winter resident. Similar to the King Rail in habits. Taken February 28 (Taylor).

SORA. *Porzana carolina*. Transient, September 8–December 23; no positive spring records.

FLORIDA GALLINULE. *Gallinula chloropus cachinnans*. One record, a specimen picked up alive on a road by Bill Hogan and procured by Odum October 16, 1934.

AMERICAN COOT. *Fulica americana americana*. Mostly fall transient, occasional in winter and spring, October 23–April 8. May 2, 1901 (G. S. MacNider).

## Family CHARADRIIDAE. Plovers, Turnstones, and Surf-birds

\*KILLDEER. *Oxyechus vociferus vociferus*. Resident. Commonest in winter.

## Family SCOLOPACIDAE. Woodcock, Snipe, and Sandpipers

AMERICAN WOODCOCK. *Philohela minor*. Resident. Commonest in fall migration, late November and early December. Wet thickets.

WILSON'S SNIPE. *Capella delicata*. Winter resident, September 9–May 12. Occurs in large flocks in spring. Also, one seen June 18, 1934 (Breckenridge). Wet or marshy meadows.

SPOTTED SANDPIPER. *Actitis macularia*. Common transient, April 12–May 21 and July 15–September 21. Mud flats, exposed creek banks and lake shores.

EASTERN SOLITARY SANDPIPER. *Tringa solitaria solitaria*. Common transient, April 18–May 20 and July 16–October 15. Often associated with the preceding.

GREATER YELLOW-LEGS. *Totanus melanoleucus*. Scarce transient, May 3; October 15–November 18.

LESSER YELLOW-LEGS. *Totanus flavipes*. Scarce transient. So far recorded only in spring, April 27–May 3.

PECTORAL SANDPIPER. *Pisobia melanotos*. Scarce transient. Specimens taken March 29, 1931; November 18, 1933; and September 19, 1934.

LEAST SANDPIPER. *Pisobia minutilla*. Scarce transient. So far recorded only in spring, May 5–May 21.

#### Family LARIDAE. Gulls and Terns

HERRING GULL. *Larus argentatus smithsonianus*. Casual visitant, spring and fall. Normally residing on the coast, this "sea gull" sometimes wanders or is driven far inland. A large flock appeared on the lake April 16, 1933, and some remained until April 22. In the fall of 1934 they again appeared, and exhausted birds were secured December 1 and December 4. In both cases their appearance followed widespread heavy rains.

BONAPARTE'S GULL. *Larus philadelphia*. Rare visitant; one record, an individual in winter plumage observed carefully by Odum November 13, 1932, at the lake.

COMMON TERN. *Sterna hirundo hirundo*. Rare visitant; one bird observed October 15, 1933, at the lake (Taylor, Breckenridge, and Odum).

BLACK TERN. *Chlidonias nigra surinamensis*. Scarce fall transient, August 24–September 17. Also two immature birds June 28, 1932. Unlike most Gulls and Terns of the Atlantic coast the Black Tern occurs regularly inland. During migration subsists mainly on insects taken on the wing.

#### Family COLUMBIDAE. Pigeons and Doves

\*EASTERN MOURNING DOVE. *Zenaidura macroura carolinensis*. Permanent resident. Long breeding season.

PASSENGER PIGEON. *Ectopistes migratorius*. This once abundant now extinct species obtains a place on the list by virtue of one taken by K. P. Battle, Jr., 1887.

#### Family CUCULIDAE. Cuckoos, Roadrunners, and Anis

\*YELLOW-BILLED CUCKOO. *Coccyzus americanus americanus*. "Rain crow." Fairly common summer resident. April 25–October 17.

BLACK-BILLED CUCKOO. *Coccyzus erythrophthalmus*. Apparently occurring only as a rare transient; October 3, 1932, and September 10, 1934.

#### Family TYTONIDAE. Barn Owls

BARN OWL. *Tyto alba pratincola*. Few records. Specimen taken January 26, 1909, by T. E. Hester. Two have been brought to the Zoology Department, one of them to Dr. H. V. Wilson eighteen years ago, the other killed by C. L. Rich near Mt. Carmel (2 miles south of town) on May 15, 1931. Mr. Roy Brown tells us that an owl which he is positive was a Barn Owl spent the winter of 1930-31 in his barn. Nocturnal and very secretive, the presence of this owl is often not suspected.

#### Family STRIGIDAE. Typical Owls

\*EASTERN SCREECH OWL. *Otus asio naevius*. Resident, fairly common; locally present in town.

GREAT HORNED OWL. *Bubo virginianus virginianus*. Resident, scarce. Occasionally specimens dead or alive have been brought in from the surrounding countryside, but in the immediate vicinity of town, at least, it seems to be very rare. Several times we have thought that we heard it at a distance, but could not be positive; we have never seen one in the wild here. Pearson in 1898 gives it status then as follows: "For a large bird the horned owl is a fairly common resident in this region."

NORTHERN BARRED OWL. *Strix varia varia*. "Hoot owl." Common resident; in timber tracts and lowgrounds. Very noisy at times and frequently attracts the attention of residents in the wooded outskirts of town.

#### Family CAPRIMULGIDAE. Goatsuckers

CHUCK-WILL'S-WIDOW. *Antrostomus carolinensis*. Scarce spring transient and perhaps rare summer resident, April 16, 1930; April 23, 1931; April 24, 1934. Pearson heard one May 20, 1899. "During the summers of 1902 and 1903 I quite frequently heard the chuck-will's-widow calling in the woods bordering the campus" (G. S. MacNider).

EASTERN WHIP-POOR-WILL. *Antrostomus vociferus vociferus*. Common summer resident. Earliest arrival, March 31.

EASTERN NIGHTHAWK. *Chordeiles minor minor*. Summer resident, April 25-September 20. Commonest during migrations, especially in fall from the middle of August to the middle of September. April 11-October 7 (Feild).

## Family MICROPODIDAE. Swifts

\*CHIMNEY SWIFT. *Chaetura pelasgica*. Common summer resident, April 4–October 10. March 31 (Feild).

## Family TROCHILIDAE. Hummingbird

\*RUBY-THROATED HUMMINGBIRD. *Archilochus colubris*. Common summer resident, April 4–October 10.

## Family ALCEDINIDAE. Kingfishers

\*EASTERN BELTED KINGFISHER. *Megaceryle alcyon alcyon*. Resident. Uncommon in winter, common in summer. Occupied nests, April 12 and May 1. Creeks, University Lake, and ponds.

## Family PICIDAE. Woodpeckers

NORTHERN FLICKER. *Colaptes auratus luteus*.

\*SOUTHERN FLICKER. *Colaptes auratus auratus*. Common resident. Eggs May 20. Frequents woods and more open country alike.

\*SOUTHERN PILEATED WOODPECKER. *Ceophloceus pileatus pileatus*. Resident. A few can always be found. A pair nested almost within the town limits in 1931, and again in 1934 in another unexpected location.

\*RED-BELLIED WOODPECKER. *Centurus carolinus*. Common resident, especially along water courses.

\*RED-HEADED WOODPECKER. *Melanerpes erythrocephalus*. Common resident, but local in distribution. Less common in winter. Often conspicuous on the University campus. Eggs May 7.

YELLOW-BELLIED SAPSUCKER. *Sphyrapicus varius varius*. Common winter resident, October 3–April 17. The only injurious woodpecker. April 26 (Feild).

\*SOUTHERN HAIRY WOODPECKER. *Dryobates villosus auduboni*. Common resident. A bit more shy than the downy.

\*SOUTHERN DOWNTY WOODPECKER. *Dryobates pubescens pubescens*. Common resident. Everywhere.

RED-COCKADED WOODPECKER. *Dryobates borealis*. Recorded only by Alexander Feild: "I found it a not uncommon bird in Battle's Park and other neighboring woods—seen by me five times in the months of March and April, 1909, the latest being on April 17."

## Family TYRANNIDAE. Flycatchers

EASTERN KINGBIRD. *Tyrannus tyrannus*. Common summer resident. Earliest date April 17. Open country. September 3 (Feild).

\*NORTHERN CRESTED FLYCATCHER. *Myiarchus crinitus boreus*. Common summer resident, April 16–September 25. Woods.

\*EASTERN PHOEBE. *Sayornis phoebe*. Common resident. More common in winter. Under bridges and porch roofs are its favorite nesting places.

\*ACADIAN FLYCATCHER. *Empidonax virescens*. Common summer resident, April 25–September 23. Eggs June 1. Characteristic of the many heavily-wooded streams around Chapel Hill.

\*EASTERN WOOD PEWEE. *Myiochanes virens*. Common summer resident, April 24–October 14. Eggs May 10. Everywhere in woods.

## Family ALAUDIDAE. Larks

NORTHERN HORNED LARK. *Otocoris alpestris alpestris*.

PRAIRIE HORNED LARK. *Otocoris alpestris praticola*. Irregular in winter. Observed in only two winters out of six: 1932–33 and 1933–34 at irregular dates from November 10 to January 6. November 23, 1898 (Pearson).

## Family HIRUNDINIDAE. Swallows

TREE SWALLOW. *Iridoprocne bicolor*. Common transient, April 8–April 28 and September 10–September 19.

BANK SWALLOW. *Riparia riparia riparia*. Scarce transient, April 16–May 12. No fall records.

\*ROUGH-WINGED SWALLOW. *Stelgidopteryx ruficollis serripennis*. “Bank Swallow.” Common summer resident. Earliest date March 28. Eggs May 21; young in nest June 25. Water.

BARN SWALLOW. *Hirundo erythrogaster*. Common transient, April 8–May 21 and August 10–September 19.

NORTHERN CLIFF SWALLOW. *Petrochelidon albifrons albifrons*. Scarce transient, May 3, September 10, and September 12.

\*PURPLE MARTIN. *Progne subis subis*. Common transient, particularly in late summer, but only, at present, a rare summer resident. March 22–September 10. We know of no stable colony in our vicinity at the present time, but there have been nesting birds in the town in the past few years, and birds are now occasionally seen during the breeding season.

## Family CORVIDAE. Jays and Crows

\*NORTHERN BLUE JAY. *Cyanocitta cristata cristata*. Common resident. Eggs May 7.

EASTERN CROW. *Corvus brachyrhynchos brachyrhynchos*.

\*SOUTHERN CROW. *Corvus brachyrhynchos paulus*. Common resident.

## Family PARIDAE. Titmice

\*CAROLINA CHICKADEE. *Penthestes carolinensis carolinensis*. Common resident. Eggs March 30. Woods and wooded places.

\*TUFTED TITMOUSE. *Baeolophus bicolor*. Common resident. Eggs March 29. Woods.

## Family SITTIDAE. Nuthatches

\*WHITE-BREASTED NUTHATCH. *Sitta carolinensis carolinensis*. Common resident. Large oaks.

RED-BREASTED NUTHATCH. *Sitta canadensis*. Irregular winter visitor, October 10–May 21. Observed in winters 1929–30, 1931–32, 1933–34. Entirely absent in other winters. Pines, usually high up among small limbs.

\*BROWN-HEADED NUTHATCH. *Sitta pusilla pusilla*. Local resident. Bird digging cavity March 18; eggs March 29. Open pine woods. Except at breeding season almost always observed in companies, probably family groups.

## Family CERTHIDAE. Creepers

BROWN CREEPER. *Certhia familiaris americana*. Fairly common winter resident, October 10–April 20.

## Family TROGLODYTIDAE. Wrens

\*EASTERN HOUSE WREN. *Troglodytes aedon aedon*. Summer resident. Several years ago we considered it scarce and as occurring only as a transient, but in the past two or three years it has become a fairly common, though local, breeder.

EASTERN WINTER WREN. *Nannus hiemalis hiemalis*. Common winter resident, September 23–April 28. Tangles near water.

\*CAROLINA WREN. *Thryothorus ludovicianus ludovicianus*. Common resident. Often nests in unexpected places about dwellings. Eggs March 26.

BEWICK'S WREN. *Thryomanes bewicki bewicki*. Winter visitor. Our only record is a bird which Dr. Valentine observed off and on at his home February and March 1935. Sang frequently.

LONG-BILLED MARSH WREN. *Telmatodytes palustris palustris*. Scarce transient, April 28–May 9 and September 20–October 7.

SHORT-BILLED MARSH WREN. *Cistothorus stellaris*. Scarce transient, April 28–May 12 and August 19–October 7.

Family MIMIDAE. Mockingbirds and Thrashers

\*EASTERN MOCKINGBIRD. *Mimus polyglottos polyglottos*. Common resident. Open locations, especially near habitations.

\*CATBIRD. *Dumetella carolinensis*. Common summer resident, April 18–October. Also recorded in early winter: November 24, 1934; December 23, 1931, 1933, and 1934. And March 21, 1935. Shrubbery and thickets.

\*BROWN THRASHER. *Toxostoma rufum*. Common resident, less common in winter. Eggs April 30. Shrubbery and thickets.

Family TURDIDAE. Thrushes, Bluebirds, Stonechants, Solitaires

EASTERN ROBIN. *Turdus migratorius migratorius*.

\*SOUTHERN ROBIN. *Turdus migratorius achrusterus*. Common resident. Abundant during migrations. In winter, flocks in woods and creek bottoms.

\*WOOD THRUSH. *Hylocichla mustelina*. Common summer resident, April 7–October 13. Eggs May 10. Very characteristic of all woodlands.

EASTERN HERMIT THRUSH. *Hylocichla guttata faxoni*. Common winter resident, October 21–April 23. We have heard this famed songster sing not infrequently while with us, but although it sometimes reaches the volume, it never approaches the quality of tone which it achieves in its northern nesting grounds.

OLIVE-BACKED THRUSH. *Hylocichla ustulata swainsoni*. Common transient, April 22–May 18 and September 18–October 15. Several specimens have been taken.

VEERY. *Hylocichla fuscescens fuscescens*. Uncommon transient, May 8–May 23; no fall records.

\*EASTERN BLUEBIRD. *Sialia sialis sialis*. Common resident. Eggs April 5. Gathers in small flocks in winter.

## Family SYLVIIDAE. Gnatcatchers and Kinglets

\*BLUE-GRAY GNATCATCHER. *Poliopila caerulea caerulea*. Common summer resident, March 24–October 4. Begins nesting almost immediately on its arrival in spring. Along water courses.

EASTERN GOLDEN-CROWNED KINGLET. *Regulus satrapa satrapa*. Common winter resident, October 10–April 17. Pine woods.

EASTERN RUBY-CROWNED KINGLET. *Corthylio calendula calendula*. Common winter resident, September 29–May 6. Less common than the preceding in winter, but becomes abundant in spring migration.

## Family MOTACILLIDAE. Wagtails and Pipits

AMERICAN PIPIT. *Anthus spinolella rubescens*. Winter resident, November 7–April 4. Seems to be commonest in early winter. Flocks in open fields. October 17 (Feild).

## Family BOMBYCILLIDAE. Waxwings

CEDAR WAXWING. *Bombycilla cedrorum*. Resident. Irregular in occurrence at all times and scarce in summer; only a few scattered records between May and October. No breeding records.

## Family LANIIDAE. Shrikes

LOGGERHEAD SHRIKE. *Lanius ludovicianus ludovicianus*.

MIGRANT SHRIKE. *Lanius ludovicianus migrans*. Scarce; irregular, scattered dates, mostly in winter, as follows: December 10, 1930; November 15, 1931; January 4, September 9, 1932; January 1 and 3, July 10, 1933; February 24, April 29, September 10 and 15, 1934.

## Family STURNIDAE. Starlings

\*STARLING. *Sturnus vulgaris vulgaris*. Common resident. Introduced into this country in 1891. As nearly as we can tell was first observed in Chapel Hill in the winter of 1925. Now breeds commonly. Nest containing young birds noted February 27 (Breckenridge).

## Family VIREONIDAE. Vireos

\*WHITE-EYED VIREO. *Vireo griseus griseus*. Common summer resident, earliest arrival March 25. Thickets and tangles, especially along water.

\*YELLOW-THROATED VIREO. *Vireo flavifrons*. Common summer resident, April 3–October 7. Inhabits woods and shade trees as the Red-eye, but not so numerous.

BLUE-HEADED VIREO. *Vireo solitarius solitarius*.

\*MOUNTAIN SOLITARY VIREO. *Vireo solitarius alticola*. The Solitary Vireo is most common as a transient from about March 16 to May and from the middle of September to November, but is also a local summer resident in certain pine woods and occurs sparingly in winter (January 2 and 3, 1934). *Alticola* is the breeding form and *solitarius* the transient form as given by the *A. O. U. Check-List*.

\*RED-EYED VIREO. *Vireo olivaceus*. Common summer resident, April 16–October 11. Everywhere in woods.

#### Family COMPSOTHLYPIDAE. Wood Warblers

\*BLACK AND WHITE WARBLER. *Mniotilla varia*. Summer resident, commonest during the migrations, March 18–October 12. Eggs May 10

PROTHONOTARY WARBLER. *Protonotaria citrea*. One record so far, May 5, 1934 (Taylor, Breckenridge; New Hope swamp). A swamp-loving lower austral species; reported as regular summer resident at Raleigh.

WORM-EATING WARBLER. *Helmitheros vermivorus*. Scarce transient, April 27–May 5 and August 31–September 5; one summer record, June 27, 1931. A low-ranging bird frequenting thickets.

GOLDEN-WINGED WARBLER. *Vermivora chrysoptera*. Scarce but regular transient, more frequent in fall; April 28–May 4 and August 30–September 12.

BLUE-WINGED WARBLER. *Vermivora pinus*. Scarce transient: May 2, 3, and September 3, 7, 20.

BREWSTER'S WARBLER. *Vermivora leucobronchialis*. This hybrid between the two preceding species was observed under excellent conditions August 25, 1932 (Odum).<sup>1</sup> A specimen taken at Raleigh September 6, 1888, is the only other record for the state.

TENNESSEE WARBLER. *Vermivora peregrina*. Scarce fall transient, September 12–October 14. Rare in spring, specimen taken by Taylor May 3, 1932, and another seen by Dr. Valentine May 2, 1932, are our only records which, however, are the first spring records for the state.<sup>2</sup> It has been previously thought that the Tennessee Warbler migrates north wholly by way of the Mississippi Valley, but regular spring records from Washington, D. C., as well as our records would indicate that this is not entirely true.

<sup>1</sup> See "The Auk," Jan., 1933 (Vol. L, No. 1).

<sup>2</sup> *Ibid.*

NORTHERN PARULA WARBLER. *Compsothlypis americana pusilla.*

SOUTHERN PARULA WARBLER. *Compsothlypis americana americana.* Summer resident, April 7 to October 11, but apparently does not breed in this vicinity. It is most common in late summer and fall and least common at breeding time (May, June); however, singing individuals have been observed throughout the latter period. The species has been reported breeding in many other parts of the state, especially in the eastern section where *Usnea* "moss" (lichen), in which it so often builds, is plentiful. A bird of the tree tops. April 3 (Feild).

\*EASTERN YELLOW WARBLER. *Dendroica aestiva aestiva.* Summer resident, not common; earliest arrival April 7. Fledglings observed July 7. September 20 (Feild).

MAGNOLIA WARBLER. *Dendroica magnolia.* Transient, common in fall, less common in spring: May 11–May 17 and August 29–October 19.

CAPE MAY WARBLER. *Dendroica tigrina.* Transient, April 21–May 7 and October 2–October 29. Usually a rather rare bird but sometimes occurs in numbers as between October 15 and 25, 1933.

BLACK-THROATED BLUE WARBLER. *Dendroica caerulescens caerulescens.* Common transient, commonest in spring; April 17–May 20 and September 8–October 10.

MYRTLE WARBLER. *Dendroica coronata.* Common winter resident, October 10–May 16. In April and early May it becomes very abundant, the wintering numbers being increased many fold by migrating birds from further south.

BLACK-THROATED GREEN WARBLER. *Dendroica virens virens.* Transient, fairly common in fall, less common in spring; April 19–May 24 and September 15–October 10.

BLACKBURNIAN WARBLER. *Dendroica fusca.* Transient, rare in spring, common in fall; April 30–May 19 and August 31–October 11.

\*YELLOW-THROATED WARBLER. *Dendroica dominica dominica.* Common summer resident, March 18–October 6. Commonest along the creeks but also nests in upland woods.

CHESTNUT-SIDED WARBLER. *Dendroica pensylvanica.* Transient, commonest in fall; April 25–May 15 and August 25–September 29.

BAY-BREASTED WARBLER. *Dendroica castanea.* Transient, rare in spring, May 11 and 12, 1933, only records; apparently much more common in fall. Although the Bay-breast and the next species, the Black-poll, are very different in the spring plumages they are so much alike in the fall that identification without specimens is hazardous; if there is a large distinct chestnut side patch the bird can be named a Bay-breast,

but if there is little or no chestnut, as in the majority of birds, positive identification of the living bird, we think, is impossible. Therefore, we will say that a specimen taken by Odum October 7, 1934 (and two taken by Pearson October 2 and 8, 1897) are the only positive fall records, but that we have enough fairly positive records (chestnut-sided individuals) to indicate that the species is not uncommon in the fall.

**BLACK-POLL WARBLER.** *Dendroica striata*. Transient, very common in spring, April 20–June 1, apparently much rarer in fall. We have a number of sight records but are inclined to think some of them at least should fall under the Bay-breast, therefore, all are discarded. The only positive fall records are: Single specimens taken by Breckenridge September 1933, Odum October 14, 1934, and Pearson October 9, 1897. More specimens will have to be taken to clarify the fall status of the Bay-breast and the Black-poll here.<sup>3</sup>

\***NORTHERN PINE WARBLER.** *Dendroica pinus pinus*. Common resident. Eggs April 15. Almost a part of the pines themselves.

\***NORTHERN PRAIRIE WARBLER.** *Dendroica discolor discolor*. Common, somewhat local summer resident; April 10–October 1. Bush covered fields.

**PALM WARBLER.** *Dendroica palmarum palmarum*.

**YELLOW PALM WARBLER.** *Dendroica palmarum hypochrysea*. Irregular transient, March 23–April 29 and September 11–October 25.

\***OVENBIRD.** *Sieurus aurocapillus*. Common summer resident, commonest during the migrations, April 5–October 8. Eggs May 12. Woods with not too much undergrowth.

**NORTHERN WATER-THRUSH.** *Seiurus noveboracensis noveboracensis*, Common transient, April 22–May 16 and August 28–October 3. Very similar to the next in plumage but notes quite different.

\***LOUISIANA WATER THRUSH.** *Seiurus motacilla*. Common summer resident. Earliest arrival, March 18. Streams.

\***KENTUCKY WARBLER.** *Oporornis formosus*. Common summer resident, earliest arrival, April 28. Damp ravines.

**NORTHERN YELLOW-THROAT.** *Geothlypis trichas brachidactyla*.

\***MARYLAND YELLOW-THROAT.** *Geothlypis trichas trichas*. Common

<sup>3</sup> In a recent article (Wilson Bulletin, Sept. 1934) on the distribution of these two warblers in the Southeast, Thomas Burleigh concluded after field work in western North Carolina, South Carolina, and Georgia that the Black-poll in fall, south of Washington, D. C., at least, migrates chiefly on the coast and is therefore rare in the interior at that season. This agrees with the facts set down above, except that the Black-poll does occur at Chapel Hill in fall; how common it is we can not say as yet.

summer resident, March 24–October 18. Also December 23, 1934. Everywhere in weeds, tangles, and thickets in open country.

\*YELLOW-BREASTED CHAT. *Icteria virens virens*. Common summer resident, April 22–September 20. Thickets in open country.

\*HOODED WARBLER. *Wilsonia citrina*. Common summer resident, April 9–September 28. Eggs May 11. Lush growth along woodland streams.

WILSON'S WARBLER. *Wilsonia pusilla pusilla*. Rare transient, September 23, 1933, only record (Odum, Breckenridge).

CANADA WARBLER. *Wilsonia canadensis*. Uncommon transient, May 5–May 17 and August 29–September 16.

\*AMERICAN REDSTART. *Setophaga ruticilla*. Common summer resident, April 8–October 11. Eggs May 19. Abundant everywhere in woods during migrations, restricted to water courses during breeding season.

#### Family PLOCEIDAE. Weaver Finches

\*ENGLISH SPARROW. *Passer domesticus domesticus*. Common resident; fortunately not over abundant at Chapel Hill.

#### Family ICTERIDAE. Meadowlarks, Blackbirds, Orioles

BOBOLINK. *Dolichonyx oryzivorus*. Irregular transient, April 13–May 5 and September 10–September 20. May 20 (Pearson), April 3, 1908 (Feild).

EASTERN MEADOWLARK. *Sturnella magna magna*.

\*SOUTHERN MEADOWLARK. *Sturnella magna argutula*. "Field Lark." Common transient, fairly common winter resident, local summer resident. Eggs May 15. Grassy fields.

\*EASTERN RED-WINGED BLACKBIRD. *Agelaius phoeniceus phoeniceus*. Common resident. Large flocks during migrations and in winter; breeds in colonies in suitable marshy places.

\*ORCHARD ORIOLE. *Icterus spurius*. Fairly common summer resident, April 23–August 1. Groves in vicinity of open country.

BALTIMORE ORIOLE. *Icterus galbula*. Scarce transient; May 4 (1930) and August 23–September 10.

RUSTY BLACKBIRD. *Euphagus carolinus*. Winter resident, commonest during the migrations, November 5–April 22. October 17, 1900 (G. S. MacNider).

PURPLE GRACKLE. *Quiscalus quiscula quiscula*.

BRONZED GRACKLE. *Quiscalus quiscula aeneus*. Transient and less

common winter resident, October 7–March 28. Of six specimens of grackle taken five have been Bronzed and one Purple.

COWBIRD. *Molothrus ater ater*. Apparently rare. Two records, December 18 and 23, 1934.

#### Family THRAUPIDAE. Tanagers

SCARLET TANAGER. *Piranga erythromelas*. Common transient, April 26–May 18 and September 16–October 15.

\*SUMMER TANAGER. *Piranga rubra rubra*. “Summer redbird.” Common summer resident, April 7–October 1. Woods.

#### Family FRINGILLIDAE. Grosbeaks, Finches, Buntings, Sparrows

\*EASTERN CARDINAL. *Richmondena cardinalis cardinalis*. “Redbird.” Common resident. Eggs April 5.

ROSE-BREASTED GROSBEAK. *Hedymeles ludovicianus*. Uncommon transient, April 24–May 9 and September 18–October 12.

\*EASTERN BLUE GROSBEAK. *Guiraca caerulea caerulea*. Uncommon summer resident, April 28–September 12.

\*INDIGO BUNTING. *Passerina cyanea*. Common summer resident, earliest arrival April 25. Open country.

EASTERN EVENING GROSBEAK. *Hesperiphona vespertina*. Two individuals taken by Dr. W. C. Coker March 8, 1922.

EASTERN PURPLE FINCH. *Carpodacus purpureus purpureus*. Common winter resident, September 12–April 24. Often very common in spring feeding on buds of elms and other trees.

NORTHERN PINE SISKIN. *Spinus pinus pinus*. Erratic winter visitor, December 12–January 10; observed winters of 1931–32 and 1933–34. April 23–May 6, 1911 (Feild).

\*EASTERN GOLDFINCH. *Spinus tristis tristis*. Common resident. Young in nest September 4. Like the Purple Finch very conspicuous in budding trees in early spring. Flocks for a large part of the year.

RED-EYED TOWHEE. *Pipilo erythrophthalmus erythrophthalmus*. Common winter resident, October to May, rare summer resident. Pair observed continually summer of 1931 and at another place in 1932, but no nest found; immature bird with streaked breast July 21, 1930.

EASTERN SAVANNAH SPARROW. *Passerculus sandwichensis savanna*, Common winter resident, September 9–May 12. One taken June 22 1933, (Taylor) was badly infected with parasitic worms. Grassy fields, damp or dry.

EASTERN GRASSHOPPER SPARROW. *Ammodramus savanarum aus-*

*tralis*. Uncommon summer resident, earliest arrival April 23. Pearson (1898) states "seen in winter and spring," but gives no specific dates.

EASTERN HENSLow SPARROW. *Passerherbulus henslowi susurrans*. Not uncommon summer resident, April 28–October 7. As far as we are aware this species has not been reported summering south of northern Virginia.<sup>4</sup> Female ready to lay taken (Taylor) and several pairs have shown unmistakable evidences of breeding. Damp, lush meadows.

EASTERN VESPER SPARROW. *Pooecetes gramineus gramineus*. Irregular winter visitor, October 28–April 24.

\*BACHMAN'S SPARROW. *Aimophila aestivalis bachmani*. Rare summer resident. Birds have been observed and heard at at least two separate localities (Odum). Nest recorded and nesting bird taken by Atkinson.

SLATE-COLORED JUNCO. *Junco hyemalis hyemalis*. "Snowbird." Common winter resident, October 22–May 4. Everywhere.

EASTERN TREE SPARROW. *Spizella arborea arborea*. One seen with White-throats January 4, 1935, by Dr. Valentine. Attempts to collect failed. "Listed by Prof. Atkinson probably as a winter occurrence" (Pearson); the latter statement alone in the absence of details or specimens would not be enough to keep the species on the list, in our opinion.

\*EASTERN CHIPPING SPARROW. *Spizella passerina passerina*. Common summer resident, March to November, local and irregular winter resident; observed winters of 1931–32 and 1933–34. Lawns and gardens in summer.

\*EASTERN FIELD SPARROW. *Spizella pusilla pusilla*. Common resident. Bush and brier covered fields.

WHITE-THROATED SPARROW. *Zonotrichia albicollis*. Common winter resident, September 29–May 17. Everywhere.

EASTERN FOX SPARROW. *Passerella iliaca iliaca*. Fairly common winter resident, November 5–April 7. Thickets.

SWAMP SPARROW. *Melospiza georgiana*. Common winter resident, October 6–May 21. Damp, boggy, marshy or swampy places.

EASTERN SONG SPARROW. *Melospiza melodia melodia*. Common winter resident, September 20–May 3. Thickets and hedgerows, especially along water.

#### THE HYPOTHETICAL LIST

(Records of the following species are not considered positive)

GREEN-WINGED TEAL. *Nettion carolinense*. March 5, 1934, not positive of identification (Breckenridge and Hairston). Should occur.

<sup>4</sup> See "The Auk," April 1933.

AMERICAN MEGANSER. *Mergus merganser americanus*. March 22, 1934, seven large mergansers, identification not positive. Should occur.

PHILADELPHIA VIREO. *Vireo philadelphicus*. May 2, one bird, not absolutely sure (Dr. Valentine). A rare transient species.

LINCOLN SPARROW. *Melospiza lincolni lincolni*. April 28, not positive (Dr. Valentine). A more western species; would be casual here in migrations.

#### APPENDIX

##### A LIST OF THE SPECIES FIRST RECORDED DURING OUR WORK, 1928-1935: 50 SPECIES

Horned Grebe	Greater Yellowlegs
Double-crested Cormorant	Lesser Yellowlegs
Snowy Egret	Pectoral Sandpiper
Little-blue Heron	Least Sandpiper
Black-crowned Night Heron	Herring Gull
Least Bittern	Bonaparte's Gull
Mallard	Common Tern
Black Duck	Black Tern
American Pintail	Black-billed Cuckoo
Blue-winged Teal	Bank Swallow
Redhead	Cliff Swallow
Ring-neck Duck	Red-breasted Nuthatch
Canvas-back	Bewick's Wren
Lesser Scaup	Long-billed Marsh Wren
American Golden-eye	Short-billed Marsh Wren
Buffle-head	Starling (introduced)
Ruddy Duck	Prothonotary Warbler
Hooded Merganser	Golden-winged Warbler
Red-breasted Merganser	Blue-winged Warbler
Osprey	Brewster's Warbler (a hybrid)
Pigeon Hawk	Tennessee Warbler
Ring-necked Pheasant (introduced)	Wilson's Warbler
King Rail	Canada Warbler
Virginia Rail	Cowbird
Florida Gallinule	Henslow Sparrow

UNIVERSITY OF NORTH CAROLINA,  
CHAPEL HILL, N. C.

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**EXPLANATION OF PLATE 64**

Fig. 1. In the heart of Strowd's lowgrounds in winter. Haunt of the Wood Duck, Red-bellied Woodpecker, Red-winged Blackbird, Song and Swamp Sparrow, and many others. Photograph by Odum.

Fig. 2. Wood Thrush, nest and young in a Dogwood. Photograph by Odum.

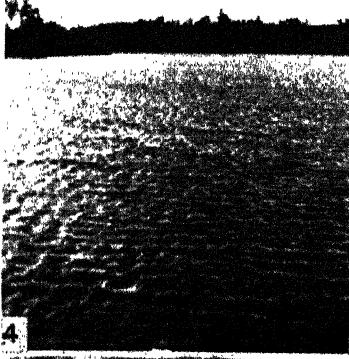
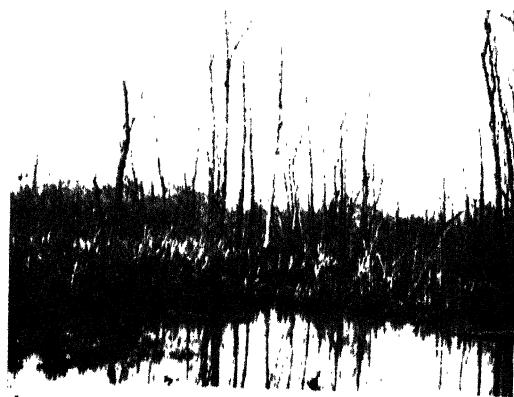
Fig. 3. Woods in spring on Brierbridge Lane; dogwoods blooming, pines and oaks. The haunt of many woodland species and a favorite stop-over for transients. Photograph by Odum.

Fig. 4. View across University Lake, a 210-acre artificial lake with a  $8\frac{1}{2}$  mile shore line. Photograph by Coker.

Fig. 5. Carolina Chickadee and White-breasted Nuthatch at feeding station in winter. A good type of window feeding station supplying suet (in cage) and cracked nuts (on shelf). Photograph by Odum.

Fig. 6. The Mother Tanager eats in style. Eugene Odum's tame wild female Summer Tanager which had the remarkable record of returning for five summers (1928-1933). Photograph by Odum.

PLATE 64





SPECIATION IN STENIRIDIA, A GROUP OF CYCHRINE  
BEETLES (FAMILY CARABIDAE, GENUS SCAPHINOTUS)

By J. M. VALENTINE

PLATES 65-73

The species comprising the subgenus *Steniridia*, Casey, are typically highland-inhabiting forms restricted to the moist, deciduous and coniferous forests of the Appalachian uplift south of the line of southernmost glaciation. Their range is roughly delimited by the Ohio and Potomac Rivers on the north and by the five hundred foot contour line on the south and east. Their western extension into Kentucky and Tennessee has not definitely been determined. In numbers both of individuals and of species, the group is most abundantly represented in the higher mountain masses, preferring an altitude of three thousand feet or more. However, at least three species may have in the past descended river valleys for these forms are now found thriving in much lower altitudes along the Potomac and Ohio Rivers and on the North Carolina and Alabama piedmont. In these cases, the insects occur in the upland type of stream-side forest rather than in that characteristic of the flood plains.

The evolution of *Steniridia* into species follows a course parallel to speciation in other flightless, essentially non-migratory, mountain-dwelling beetles. Differentiation can be directly correlated with isolation, the more complete the latter, the more fundamental the dichotomy. Seven species in all are recognized herein. Of these, four (*andrewsi*, *violacea*, *guyoti* and *ridingsi*) are of the stem species type with relatively wide, overlapping ranges over which numerous geographic races or subspecies can be found. Living with these stem species, but occupying very limited areas, are two closely related species (*aeneicollis* and *tricarinata*), evidently isolation products. A single species (*lodgingi*) represents a third category—that of an isolated form living out of contact with any other member of the group (Pl. 65).

The ability of the above-mentioned forms to retain their distinctiveness in spite of their association in identical ecological frames is taken as indication that they must be considered true species in the biological sense of the word. There is no evidence at present that they will hy-

bridize under natural conditions and a great deal of evidence, supplied by the *aedeagus* and its internal chitinizations, exists to support the theory that they are anatomically prevented from so doing even in event of inter-specific copulation. However, as with other organisms in nature, there probably resides in this specificity also a psycho-physiological reluctance to hybridize which may conceivably act as a potent isolation factor and thus become a cause as well as an end-product of morphogenesis.

Successful insemination depends, of course, upon the perfection of the probable lock-and-key-like relation of the genitalic elements of both sexes. The soft, everted *internal sac* of the male, bearing a more or less heavily chitinized, tongue- or spout-shaped piece, the *transfer apparatus*, at its distal extremity (Pl. 71, figs. 1-3), must be properly received by the vaginal cavity of the female so that the transfer piece reaches and fits a softer, horse-shoe-shaped organ, the *annulus*, situated on the ventral vaginal wall just posterior to the mouth of the *oviduct*. Sperm escape through the trough of the transfer apparatus and pass into the *seminal receptacle*, a cleft-like storage pocket formed by the walls of the annulus (Pl. 70, figs. 1-3). As the degree of development of this annulus seems to be in direct proportion to the extent of chitinization of the transfer apparatus, it is highly probable that the two structures interlock during coitus. Certainly their relative positions lead one to expect this.

Such a complex relationship does not lend itself to great deviation from the species standard. The internal sac and the vaginal cavity must be precise complements; any drastic departure from type, on the part of either sex, would almost certainly result in abortive or imperfect insemination. So it is not surprising to find that the structure of the male transfer piece in a given species is very constant, while differences between species in this respect are trenchant and are of a qualitative rather than a quantitative nature. On purely mechanical grounds alone, such a selective factor as the transfer piece seems quite sufficient to account for the breeding true of even closely related species of *Steniridida* when in ecological association.

With this diagnostic, internal structure are correlated less easily recognized, but taxonomically useful, external specific characters; chief among these is a secondary sexual one—the modification of the male front tarsus.

Geographic races or subspecies of *Steniridida*, on the other hand, depart from their respective stem stocks by essentially quantitative steps as

compared with species differences. The transfer piece may be a little longer or broader or thicker but its original plan remains unchanged. Much more obvious changes may occur externally in size, contour, sculpture and color, but even these seem to reflect the intensification of a few traits already obvious rather than the subtle, though often slight, remodeling of the whole organism as seen when genetically distinct species are compared. It is true that species and subspecies are relative terms; however it is quite clear that they represent separate levels of the same biological phenomenon and as such possess a definite and objective value.

A subspecies or geographic race is a population spatially separated from its parent stock or closest relative and exhibiting a mean morphogenic departure of such a low order as not to preclude crossing with the related race at the zone of contact.

Once the subspecific or secondary differential level of any group has been determined by comparison with the first-order or specific level and checked by a study of transitional forms, it is not impossible to continue the analysis deductively. Thus, specific rank may be ascribed to forms which exhibit first-order differences but which cannot be proved to breed true in nature for the simple reason that they are geographically or ecologically remote from their closest kin. Similarly, subspecific rank may be deductively assigned to forms whose connecting link with the mother colony is unknown or which are so remotely isolated from their relatives as to have lost all connection. These problems can be settled more or less satisfactorily, in *Steniridia* at least, by referring the forms in question to specific standards previously established, bearing in mind that apparent isolation is no proof either of specificity or subspecificity but that ecological association with the stock genetically closest is the best field evidence for specificity provided the points of difference include the genitalia and are of the first-order magnitude.

Under the term "variety" is included all those color phases and aberrant individuals sufficiently distinct to merit the retention of specific and subspecific names wrongly applied. These are not geographical or ecological populations—merely extreme variants within the mother colony. It is important, in this regard, to note that in all such cases considered, the aedeagi are absolutely characteristic of the parent stock and do not share in the conspicuous alterations of external contour, etc.

The above systematic criteria are used in the present synopsis of *Steniridia* in order to lend greater biological significance to the various names already in use and to stimulate the dissection and detailed study

of genitalic structures prior to future publication in this and other groups of carabids.

Especial acknowledgment is due Mr. Herbert S. Barber of the Department of Agriculture for his keen and helpful interest in this work and for his assistance, generously bestowed, in making preparations. To Dr. Edward A. Chapin and Mr. L. L. Buchanan of the National Museum the author is greatly indebted for the loan of specimens and for the privilege of dissecting the Casey types of *Steniridia*. Mr. P. J. Darlington, Jr. has very kindly consented to the loan of important material from the Museum of Comparative Zoology and from his private collection; through his courtesy the author was enabled to study and dissect the unique type of *violacea* in the Leconte collection. The following have greatly assisted the author by generously contributing valuable material for dissection and study: Dr. Henry P. Löding, Mr. E. T. Cresson, Jr., Mr. J. Mutchler, Dr. J. Chester Bradley, and Prof. David Dunavan. In Mr. Mutchler's absence, Dr. C. H. Curran most kindly extended the author the privilege of working with the collections in the American Museum. To Mr. Lane Barksdale and to Messrs. Joseph R. and Reeve Bailey, the author extends his sincere thanks for collecting for him important material in the mountains of North Carolina and Tennessee.

#### METHODS

Dissections of the genitalia of both sexes were made in Barber's relaxing fluid<sup>1</sup> after soaking the insect in this mixture for ten minutes or longer. The internal sac of the male was extracted through a lateral, longitudinal incision in the *median lobe* (penis), the connection between the sac and the apical end of the lobe remaining intact. After lifting out the basal portion of the sac with its afferential duct, the transfer piece, visible through the folds of the internal sac as a dark mass, was carefully dissected out. The inflation of the internal sac is perhaps a better method of exhibiting its chitinizations than the dissection of the median lobe; certainly the functional shape of the sac cannot otherwise be properly observed. However, unless great skill is employed, this operation more often than not results in damage or failure. Mr. H. S. Barber, using a micro-injection pipette, has achieved noteworthy results (Pl. 71, figs. 1-3); he prepared the aedeagus for inflation by soaking

<sup>1</sup> Barber's relaxing fluid: 95 per cent alcohol, 265 parts; water, 245 parts; ethyl acetate, 95 parts; benzol (benzene), 35 parts.

it in weak caustic potash and assisted the process of evagination by gently pulling the sac out of its sheath by means of a hooked needle. Meanwhile, hydrostatic pressure was applied at the basal orifice of the median lobe. To preserve the sac in its distended position, hardening agents such as strong alcohol followed by xylol may be necessary.

All measurements were made with the aid of a micrometer eye-piece graduated to tenths of millimeters. Curved surfaces were measured as the chords of those surfaces between the desired limits. As traits of contour and proportion cannot be expressed by linear measurements, an attempt was made to describe such with the aid of indices. Principal ratios were obtained in the following manner:

(1) *Head index*: The distance across the eyes (width), measured dorsally from their outer margins, divided by the distance from the outermost extremity of the mandibles in parallel position, to the anterior margin of the pronotum when the head is parallel to the latter (length).

(2) *Pronotal index*: The distance from the anterior to the posterior extremities of the pronotal margins measured in the mid-dorsal line (length) divided by the greatest transverse distance across the pronotum (width).

(3) *Elytral index*: The greatest transverse distance across the elytra (width) divided by the distance, measured along the suture, from the furthermost elytral apex to the posterior margin or apex of the scutellum (length).

(4) *Abdominal index*: The deepest measurement of the abdomen plus the elytra (height) divided by the elytral length; the former was taken, after bending the rear leg dorsally at the coxal joint, by optically placing one end of the scale on the level of the intercoxal metasternum and reading the level of the most elevated portion of the elytral suture when the longitudinal axis of the insect was oriented roughly at right angles to the scale.

(5) *Tarsal index*: The total length of the squamous pad borne on the plantar surface of the first (longest) segment of the male tarsus divided by the total length of this segment measured along the same surface.

The *total length* was obtained by adding head length, pronotal length, scutellum and elytral length, care being taken to see that the insect was closely articulated before measurement.

All illustrations are original. The photographs were taken on pano-matic film. The drawings were outlined with a camera lucida.

## Genus SCAPHINOTUS Dej.

Dejean: Spécies Général des Coléoptères, vol. 2, p. 17, 1826, Latreille's *Scaphinote*, 1822 and 1825, not being latinized, is invalid according to article 3 of International Rules of Zoological Nomenclature, 1926.

*Genotype*: *elevatus* Fabricius, Mantissa Insectorum, vol 1, p. 198, 1787.

This category is herein used in its narrow sense as a genus. It includes those deeply striate, pigmented forms having simple, undilated cheeks, heavily punctate elytral epipleura and a maximum of two pronotal marginal setae on either side. It is not within the scope of the present paper to analyze generically the various groups into which *Scaphinotus* in its broader sense might be divided. However for the sake of rendering a clearer picture of the evolution and distribution of this American supergenus, it is necessary to elevate to generic rank most of the categories which are now generally considered subgenera (Van Dyke, Csiki, etc.). Thus, in eastern North America, the multisetose *Nomaretus* of Ozarkian origin and the astriate, depigmented *Maronetus* of the southern Appalachians, both with modified cheeks, had best be treated as genera.

*Scaphinotus*, as defined above, contains three natural groups, treated here as subgenera: *Scaphinotus* s. str., *Irichroa* Newman, and *Steniridia* Casey. These possess anatomical features and ranges sufficiently characteristic to warrant their taxonomic separation. The following key is intended to bring out these differences and is applicable at least to eastern North American species of *Scaphinotus*:

I. Pronotum with wide, strongly reflexed margins. Internal sac of male chitinized throughout; transfer apparatus not or weakly differentiated, transitional with the folds of the internal sac. Widely ranging, lowland-inhabiting species as well as highland-dwelling species with restricted ranges.

A. Pronotum asetose or unisetose, margins very wide; humeral margins wide, reflexed. Internal sac in situ with conspicuous longitudinal fold or crest along membranous wall of aedeagus. The southwestern Rocky Mountains (U. S. and Mexico) ranging north and east into the Mississippi, Gulf and Atlantic lowlands

A. *Scaphinotus* (14 species)

AA. Pronotum bisetose, margins relatively narrow; humeral margins normal. Internal sac without median crest. The entire Appalachian highlands ranging from the northern portion south into the Atlantic and Gulf coastal regions

AA. *Irichroa* (1 species—*vidua*)

II. Pronotum with normal or narrow margins. Internal sac without median crest, very weakly sclerotized except for transfer apparatus, which is usually strongly reinforced with chitin, and a pair of sclerotized folds situated more proximally. Typically highland-inhabiting species of the southern Appalachians.....*Steniridia* (7 species)

Subgenus SCAPHINOTUS s. str.

*Genotype*: *elevatus* Fab.

Subgenus IRICHROA Newman

Newman: Entomological Notes. Ent. Mag., vol. 5, p. 385, 1838.

*Genotype*: *vidua* Dejean, Spécies Général des Coléoptères, vol. II, p. 12, 1826.

Subgenus STENIRIDIA Casey

Casey: Additions to Coleoptera. Mem. Coleop., vol. 11, p. 236, 1924.

*Genotype*: *andrewsi* Harris, Remarks on *Cychrus*. Bost. Jour. N. Hist., vol. 2, no. 2, 1839.

*Diagnosis*: medium to large forms (15-30 mm.) strongly convex, usually violaceous or aeneous, with relatively large head, long jaws and appendages, small cordate or conical pronotum bearing two setae on either side and with normal margination.

Casey at first (1920) retained *andrewsi* and its relatives under the genus *Irichroa* after erecting the genus *Megaliridia* for *vidua*. However, it was pointed out to him by Leng that *vidua* is the genotype of *Irichroa*; consequently he suppressed (1924) *Megaliridia* and established the genus *Steniridia* to contain the *andrewsi* group.

Thomas Casey's primary interest lay in the description of external contour and other habitus characters. Since members of the group *Steniridia* are exceedingly variable in this respect, it is not surprising that his work should result in the addition of a large number of specific names. In several instances, unit populations were divided by him into a series of component species while one of his subspecies (*tricarinata*) appears to be fundamentally (specifically) distinct from its supposed close relative (*aeneicollis*). Yet his work is of great value as it is a careful classification of the principal forms a species may assume in a given locality. His view-point is the logical outcome of the quantitative method of taxonomic analysis based upon external differences. It must be admitted that this contrasts strongly with the biological approach which

aims to discover similarities as well as differences and these of a nature as fundamental as possible.

The seven species contained in *Steniridia* are keyed below:

- I. Plantar pad on the first segment of male tarsus more than one half the total length of the first segment (tarsal index 0.51-0.82) (excepting *ridingsi intermedia*, tarsal index 0.50).
  - A. Size relatively large; if smaller than 23 mm. elytral costae interrupted and confluent on the marginal and posterior disc.
    - B. Median lobe of aedeagus normal, with conspicuous spoon-shaped transfer apparatus heavily chitinized as a separate piece.
      - C. Pronotum much constricted posteriorly; median lobe of aedeagus with quadrate transfer apparatus bearing on its convex surface, a median, longitudinal carina
        - acnicollis* (Pl. 71, figs. 1-5)
      - CC. Pronotum normal; median lobe with elongated, spatulate transfer apparatus bearing no median carina
        - andrewsi* (Pl. 72, fig. 9; Pl. 73, figs. 1-9)
    - BB. Median lobe of aedeagus elongate, with complex, folded, lightly chitinized transfer apparatus integral with the walls of the internal sac.....*tricarinata* (Pl. 71, figs. 6-7)
  - AA. Size relatively small (16-20 mm.); elytral costae not confluent; aedeagus without heavily chitinized transfer apparatus
    - ridingsi* (Pl. 72, figs. 6-8)
- II. Plantar pad on the first segment of male tarsus less than one half but greater than one third the total length of the first segment (tarsal index 0.40-0.48); median lobe of aedeagus more arcuate than in *andrewsi*, transfer apparatus discrete, tongue-shaped, bearing on its convex surface, three, deep, longitudinal carinae—one median and two lateral.....*violacea* (Pl. 71, figs. 8-10)
- III. Plantar pad on the first segment of male tarsus one third or less than one third the total length of the first segment (tarsal index 0.21-0.36).
  - A. Very convex forms (abdominal index 0.42-0.50) with confluent elytral costae; median lobe of aedeagus elongated, much constricted in basal half; transfer apparatus folded, complex, lightly chitinized, integral with walls of internal sac
    - guyoti* (Pl. 72, figs. 1-3)
  - AA. Much flattened forms (abdominal index 0.38-0.46) with cordate elytra and entire elytral costae; median lobe of aedeagus only slightly constricted near base, transfer apparatus small, discrete, heavily chitinized, deeply flanged and carinate
    - loddingi* (Pl. 72, figs. 4-5)

#### DESCRIPTIONS

For the sake of brevity and clarity, synonymy has been omitted except where it involves a name under immediate consideration. De-

tailed descriptions not of a comparative nature have also been omitted. The worker is referred to original descriptions and to Roeschke's monograph of the *Cychrini* (see bibliography) for these matters. The diagnostic characters are given in the key.

Total length is indicated by L. and elytral width by W. The indices, defined above, are abbreviated in the following manner: h. ind.—head index; p. ind.—pronotal index; e. ind.—elytral index; a. ind.—abdominal index; t. ind.—tarsal index of male.

Specimens recorded by others but not actually studied by the author are not included in this paper. Over the past three years, an effort has been made to collect in as many localities in the southern Appalachians as possible and to examine all the *Steniridia* material of the larger museums. Since a great many samples have been examined, the author feels that he can afford to overlook unverified records and thus avoid a source of taxonomic error.

### 1. *Steniridia andrewsi* Harris

This stem species is the widest ranging of the group; its various races extend unbrokenly along the Appalachian chain from southern Pennsylvania to northern Georgia while local populations are found sporadically on the piedmont and along the Ohio drainage system.

In general the larger, more brilliant and less deeply sculptured races occur in the lowland and become progressively smaller, blacker and more irregularly pitted in the higher altitudes. The same phenomenon is observable in other species.

#### 1a. *S. andrewsi* s. str. Harris

Harris, T. W.: Remarks on *Cyhrus*. *Bost. Jour. Nat. Hist.*, vol. 2, no. 2, 1839.

*Type*: ♀, not in the Harris collection in the Boston Museum; evidently lost.

*Type locality*: "North Carolina."

*Neotype* ♀: U. S. National Museum. J. M. Valentine, collector.

*Neotype locality*: Chapel Hill, Orange Co., North Carolina. (Pl. 65.)

*Neotype* ♀: L. 23.9 mm.; W. 9.4 mm.; h. ind. 0.44; p. ind. 0.89; e. ind. 0.70; a. ind. 0.44. Above, head and pronotum green-blue-black, elytra deep, brilliant, violaceous blue with greener margins; below, black, except for purplish black elytral epipleurae and yellowish brown tarsi.

*Neotopotypes*: 2♂'s (one imperfect): L. 23.0 mm.; W. 8.8 mm.; p. ind.

0.83-0.85; e. ind. 0.70-0.71; a. ind. 0.42-0.46; t. ind. 0.53. Above, deep, rather brilliant violaceous; head blacker with green reflections; below, as in neotype (Pl. 67, fig. 2).

♀ : L. 24.2 mm.; W. 9.2 mm.; h. ind. 0.41; p. ind. 0.91; e. ind. 0.67; a. ind. 0.47. Darker violaceous than male, head blue-green-black, elytra and pronotum with blue-green reflections, especially on sides.

Harris' description of *andrewsi* (from "manuscript catalog of Prof. Hentz") agrees with this lowland form and not with the more western, highland race (*montana* subsp. n.) inasmuch as the tarsi of the former are "rust-colored," the pronotum sides cordately "rounded," and the elytral striae and costae are interrupted only at the "tip." This race is of a deeper, more brilliant blue or violet, is more convex, has narrower reflexed margins throughout and has a pronotal base which is more profusely punctate than *montana*. These characters, though admittedly relative, are convincingly indicated by Harris. The elytral striae are not quite so broadly punctate as in *montana* and the irregularities in apical sculpture are more posteriorly confined. The squamous pad on the first segment of the male front tarsus extends a little more than half way to the segment's base (Pl. 69, fig. 3). The transfer apparatus of the median lobe of the aedeagus is shorter and wider than in other races of *andrewsi*; viewed from above, it has the shape of the sole of a shoe (Pl. 73, figs. 6-7).

Another reason for selecting the piedmont race of *andrewsi* as neotypical is the reference made by Harris to the source of material. He says: "Prof. Hentz" (at the University of North Carolina, Chapel Hill, N. C., 1826-30) . . . "dedicated this species to its discoverer, the son . . . of Prof. Andrews, late of the University of North Carolina." In all probability this is a lost species originally taken at Chapel Hill and only rediscovered some three years ago by the author.

*Chorology:* Under logs in oak-pine-dogwood-hickory woods along banks of woodland streams. To the author's knowledge, *andrewsi* has been found on the piedmont only at Chapel Hill where it occurs sparingly during June and October.

#### 1b. *S. andrewsi montana* subsp. n.

*Type:* ♂, U. S. National Museum. J. M. Valentine, collector.

*Allotype:* ♀, U. S. National Museum. J. M. Valentine, collector.

*Type locality:* Beech Mountain, Avery Co., North Carolina (Pl. 65).

*Type ♂*: L. 21.4 mm.; W. 8.5 mm.; h. ind. 0.42; p. ind. 0.83; e. ind. 0.73; a. ind. 0.44; t. ind. 0.77. Above, violaceous, head and pronotum with blue reflections; below, black, elytral epipleurae slightly purplish; tarsi very dark brown (Pl. 66, fig. 1).

*Allotype ♀*: L. 23.4 mm.; W. 9.3 mm.; h. ind. 0.46; p. ind. 0.83; e. ind. 0.75; a. ind. 0.48. Green-blue-black with violet reflections.

*Paratypes*: 2♂'s: L. 19.8–20.2 mm.; W. 7.6–8.2 mm.; h. ind. 0.42–0.44; p. ind. 0.83–0.85; e. ind. 0.72–0.74; a. ind. 0.47; t. ind. 0.70–0.82. Violaceous, head and pronotum with green-blue reflections.

♀: L. 23.8 mm.; W. 9.3 mm.; h. ind. 0.45; p. ind. 0.81; e. ind. 0.69; a. ind. 0.45. Color as in males.

This race is the form commonly referred to typical *andrewsi*. It differs, however, in the pronotum whose margins are wider and straighter posterior to the lateral angle which is more pronounced; in the pronotal base which is less densely punctate, sometimes almost impunctate; in the punctures of the elytral striae which are more conspicuous and produce posterior irregularities in the costae, especially along the sides, half way to the elytral base; and in the more profusely and irregularly punctate elytral epipleurae. The tarsi are almost black, are more dilated in the male and are unique in *Steniridia* in having the first segment in the male almost fully scaled beneath (Pl. 69, fig. 1).

*Chorology*: This race is relatively abundant, in its typical form, on the mountain sides and in the valleys of the high ranges of northwestern North Carolina south probably to where the French Broad River separates the northern from the southern Carolina highlands. It should be looked for where the high Carolina range extends into Virginia in the neighborhood of White Top Mt., Grayson Co. On Mt. Guyot, in the more southerly Smokies, *andrewsi* seems to be intermediate between *montana* and a still more southerly race, *parvitaralis* subsp. n. (Pl. 65; Pl. 69, fig. 7).

Type and allotype: under bark of log on south side of Beech Mountain, Banner Elk, N. C., about 5000 ft., in beech-birch-chestnut association bordering a small stream, late August, 1934. Paratypes: five males, one female, in molasses traps set in moist, rocky ravine among rhododendron and large hemlocks, 3500 ft., Banner Elk, N. C., Sept., 1934. Collector, J. M. Valentine.

Material from the following localities is essentially similar: Grandfather Mountain, Avery Co., N. C.; Little Switzerland, Dowell Co., N. C.; Mt. Mitchell, Buncombe and Yancey Cos., N. C.

*Synonymy:* 1b'. *S. andrewsi montana* var. *amplicollis* Casey

Casey, T. L.: Mem. Coleop., vol. 9, p. 174, 1920.

*Type:* ♂, U. S. National Museum. Beutenmüller, collector.

*Type locality:* "Black Mts., N. C."

*Type ♂:* L. 23 mm.; W. 8.8 mm.; h. ind. 0.45; p. ind. 0.78; e. ind. 0.68; a. ind. 0.42; t. ind. 0.715. Violaceous above (Pl. 66, fig. 2).

This is merely a broadly margined individual of *montana* and is not typical of the locality as indicated. It has been given varietal recognition by the author because it represents an extreme variant. Genitally, it is precisely similar to *montana*. Casey was definitely in error when referring it subspecifically to *violacea*; it bears no relation to this species. A "paratype" female is intermediate between *amplicollis* and typical *montana*.

The form described by Casey as *andrewsi* subsp. *reflexa* from a single female ("Black Mts., N. C." Beutenmüller, U. S. National Museum) is a less extreme variant of *montana*, having slightly more reflexed, straighter pronotal margins. Genitally, it is identical with the latter.

1c. *S. andrewsi germari* Chaudoir

Chaudoir, Baron M. de: Bull. Soc. Nat. Moscow, vol. 34, p. 5, 1861.

*Type:* ♀, location unknown.

*Type locality:* "Tennessee."

*Germari* presents quite a different habitus from *montana* with which race it is in closest geographical association. It is generally larger, more elongate and possesses a pronotum which is very characteristic, being long (sometimes as long as wide), narrow, straightsided, deeply impressed basally and often sculptured with fine transverse wrinkles and dense basal punctures. The acdeagus of the male, however, does not differ to any appreciable extent from that of race *montana* and seems to be consistent over the wide range which *germari* occupies (Pl. 73, figs. 1-5). The front tarsi of the male are dilated as in *montana* but the scaly pad of the first segment is more limited longitudinally; however, this character is unstable as evinced by variation in the colony at Uniontown, Pa. (Pl. 69, fig. 2).

*Uniontown, Pa.* (extreme variants selected from a large series): 7♂'s:  
L. 23.6-20.7 mm.; W. 8.2-9.0 mm.; h. ind. 0.43-0.48; p. ind. 0.88-0.97;  
e. ind. 0.69-0.72; a. ind. 0.41-0.44; t. ind. 0.60-0.69. Head green-

blue-black with violaceous reflections, pronotum violaceous with green-blue reflections, elytra violaceous often with aeneous reflections; sometimes insect almost black with slight purplish tint; below, as in *montana*.

4 ♀s: L. 24.2–26.9 mm.; W. 9.2–10.7 mm.; h. ind. 0.45–0.44; p. ind. 0.90–1.02; e. ind. 0.68–0.70; a. ind. 0.43. Color as in male.

*Cincinnati, Ohio:* 4 ♀s: L. 23.0–26.0 mm.; W. 9.5–10.7 mm.; p. ind. 0.93–0.96; e. ind. 0.71–0.73; a. ind. 0.44–0.46. Violaceous with green-blue or aeneous reflections.

*Pennington Gap, Va.:* 2 ♂s: L. 22.5–23.2 mm.; W. 8.8–9.1 mm.; h. ind. 0.41–0.43; p. ind. 0.88–0.93; e. ind. 0.72–0.76; a. ind. 0.43–0.46; t. ind. 0.53. Violaceous, head and pronotum darker, with blue-green reflections.

2 ♀s: L. 24.1–25.6 mm.; W. 10.2–9.3 mm.; h. ind. 0.42–0.45; p. ind. 0.88–0.98; e. ind. 0.70–0.72; a. ind. 0.46. Color same as in males.

*Mountain Lake, Va.:* 3 ♂s: L. 19.2–21.8; W. 7.3–8.2; h. ind. 0.41–0.46; p. ind. 0.86–0.90; e. ind. 0.68–70; a. ind. 0.42–0.45; t. ind. 0.70–0.77. Violaceous with green-blue reflections on darker head and pronotum.

3 ♀s: L. 23.2–24.0 mm.; W. 9.1–9.4 mm.; h. ind. 0.43–0.44; p. ind. 0.86–0.91; e. ind. 0.69–0.70; a. ind. 0.44–0.47. Color as in males excepting one very much darker green-blue specimen from the open mountain top.

*Chorology:* This is the widest ranging form of all *Steniridia*. It seems to have adapted itself to lowlands as well as high altitudes but is characteristic of the great plateau, averaging 1500 ft., which stretches from southwestern Pennsylvania in a southwesterly direction across eastern West Virginia and western Virginia and breaks up in north-eastern Tennessee, the probable type locality (Claiborne Co.). The New River, cutting across the mountain plateau at right angles, evidently is no barrier to the dispersal of this form since the insect is found on both sides and follows it, as well as the upper reaches of the Ohio, westward as far as Cincinnati. Where the higher, more eastern mountain mass of North Carolina merges with the Virginia plateau, a smaller form of *germari* is found at high altitudes (4000 ft.) which is clearly intermediate between this race and the more restricted *montana* (Mountain Lake, Giles Co., Va.). The following locality records are at hand: Uniontown, Fayette Co., Pa.; Cincinnati, Hamilton Co., Ohio; Gawley Mt., Fayette Co., W. Va.; Fairmont, Marion Co., W. Va.; Pennington

Gap, Lee Co., Va.; Harlan, Bell and Whitley Cos., Ky.; Frankfort, Franklin Co., Ky. (Pl. 65).

*Germari* inhabits the same situations as *montana* which it entirely displaces over its range. Under bark and logs in moist, mixed, deciduous forests along mountain streams is its favorite haunt. Like nearly all members of the group, it is most abundant in June and September. It is unquestionably the most frequently collected *Steniridia*, but this fact may simply reflect a wide range rather than abundance.

*Synonymy:* Slight variants within the colony at Uniontown, Pa., have been described by Casey (1920) as a species ("mutabilis") and two subspecies ("mutabilis longicollis" and "m. modulata"). The main point of difference lies in the slightly less elongated scaly pad on the first segment of the male front tarsus, a variable character. Size and contour differences were obtained by sorting sexes, "mutabilis" having a type series of five males, "longicollis" being represented by three large males and six females, and "mutabilis" being a unique male. The aedeagi were indistinguishable from typical *germari*.

1d. *S. andrewsi parvitarsalis* subsp. n.

*Type:* ♂, U. S. National museum.

*Type locality:* Clayton, Rabun Co., Georgia (Pl. 65).

*Paratypes:* 4♂s, Philadelphia Academy, U. S. National Museum, Cornell Univ., Ithaca, N. Y. 2♀s: Philadelphia Academy, Cornell Univ., Ithaca, N. Y.

*Type ♂:* L. 20.6 mm.; W. 8.5 mm.; h. ind. 0.46; p. ind. 0.86; e. ind. 0.73; a. ind. 0.48; t. ind. 0.61. Above, rather brilliant violaceous, head and pronotum darker with blue reflections; below, black, elytral epipleurae faintly purplish, tarsi yellowish brown.

*Paratypes:* 4♂s: L. 20.7–22.3 mm.; W. 8.4–8.8 mm.; h. ind. 0.42–0.46; p. ind. 0.82–0.90; e. ind. 0.70–0.72; a. ind. 0.46–0.48; t. ind. 0.60–0.67. Color as in type (Pl. 66, fig. 3; Pl. 69, fig. 5).

2♀s: L. 21.5–23.2 mm.; W. 8.7–9.3 mm.; h. ind. 0.43–0.46; p. ind. 0.86–0.90; e. ind. 0.71; a. ind. 0.48–0.50. Color as in type, a little bluer throughout.

*Parvitarsalis* is a distinct race superficially resembling *montana* but differing notably in the much less expanded front male tarsus whose first plantar pad is much reduced. It is this character which has led workers to misidentify specimens as *violacea* Lec. *Violacea* possesses

genitalic features which clearly separate it from *parvitarsalis*; the latter is barely distinguishable, genitally, from *montana* and *germari* (Pl. 73, figs. 8-9). Even in the female genital system, specific characters trenchantly intervene between *violacea* and *parvitarsalis* (Pl. 70, figs. 1-2). In color, *parvitarsalis* from its type locality is more brilliantly violaceous than *montana* from which it differs also in having yellowish brown tarsi, a more elongate pronotum with wider margins more concave posterior to the lateral angle, and an irregularly punctate pronotal base. In addition, irregularity in elytral striae is confined to the extreme margin and to the apical third of the elytra.

Specimens from the Nantahala range, North Carolina, which resemble closely a series from the "Blue Ridge Mts., N. C.", collected by Gustav Beyer, are somewhat smaller, darker and show a tendency for costal interruption characteristic of *montana*. A similar form has been taken by F. R. Mason in the southern Unaka Mountains of Tennessee. These have the following characteristics:

*Nantahala Mts., N. C.*: 3♂'s: L. 17.3-20.0 mm.; W. 7.6-8.1 mm.; h. ind. 0.44-0.48; p. ind. 0.80-0.83; e. ind. 0.72-0.81; a. ind. 0.43-0.47; t. ind. 0.64-0.69. Dark violaceous (Pl. 69, fig. 6).  
♀: L. 20.4 mm.; W. 8.0 mm.; h. ind. 0.43; p. ind. 0.87; e. ind. 0.71; a. ind. 0.46. Color as in males.

*Unaka Mts., Tenn.*: ♂: L. 21.2 mm.; W. 8.0 mm.; h. ind. 0.47; p. ind. 0.85; e. ind. 0.70; a. ind. 0.46; t. ind. 0.61. Violaceous with aeneous reflections (Pl. 69, fig. 4).

*Chorology*: *Parvitarsalis* is typically a form of the low mountains (2000-3000 ft.) of northeastern Georgia where it represents *andrewsi*. However, subraces occur in the higher altitudes (3000-4000 ft.) of those connecting ranges of the southern Blue Ridge of North Carolina which run in a northwest-southeast direction between the forks of the Little Tennessee and the Hiawassee Rivers. *Parvitarsalis* is limited on the northeast and southwest by these streams and on the west by the abrupt drop in altitude at the Tennessee line where the southern Unaka Mts. are located. In the last-named, another subrace occurs which intergrades with *montana* in the Smokies.

The following locality records are at hand: Clayton (type), Satola (paratype), Mountain City (paratypes), all in Rabun Co., Ga.; Grimshawes, Jackson Co., N. C.; Unaka Mts., Monroe Co., Tenn., 3500 ft. (Pl. 65).

In habits, *parvitarsalis* resembles *montana* and *germari*.

1e. *S. andrewsi darlingtoni* subsp. n.

*Type:* ♂, Museum of Comparative Zoology. P. J. Darlington, collector.

*Allotype:* ♀, Museum of Comparative Zoology. P. J. Darlington, collector.

*Paratype:* ♂, Museum of Comparative Zoology. P. J. Darlington, collector.

*Type locality:* Newfound Gap, Sevier Co., Tenn., 3500 ft.

*Type* ♂: L. 19.7 mm.; W. 7.4 mm.; h. ind. 0.47; p. ind. 0.81; e. ind. 0.61; a. ind. 0.43; t. ind. 0.62. Above, dark violaceous, margins and head with green-blue reflections; below, black, elytral epipleurae violaceous black, front tarsi dark yellowish brown (Pl. 66, fig. 4).

*Allotype* ♀: L. 20.8 mm.; W. 8.0 mm.; h. ind. 0.43; p. ind. 0.78; e. ind. 0.68; a. ind. 0.46. Color similar to type, darker, blue-green reflections on disc.

*Paratype* ♂: L. 16.8 mm.; W. 6.5 mm.; h. ind. 0.48; p. ind. 0.82; e. ind. 0.64; a. ind. 0.44; t. ind. 0.70. Very dark violaceous, disc with dull green reflections.

This race of *andrewsi* includes the smallest specimens the author has seen. It is much more elongate than *montana* or *parvitarsalis* and is conspicuously different in having reduced humeri. The elytral punctures are larger and more irregular and the pronotal base is rugosely punctate. The pronotal sides are distinctly concave posterior to the well defined lateral angles, though not so much so as in typical *parvitarsalis*. The basal tarsal pad in the male is more extensive than in the latter (Pl. 69, fig. 8). The aedeagi are almost indistinguishable, except in size, from other monticolous *andrewsi*.

*Chorology:* The coarse sculpturing, dark coloration, and small size reflect the conditions of high altitude under which this colony exists. A specimen from lower down (Bryson City, 2000 ft.) is less sculptured and more transverse; it serves to connect *darlingtoni* with its lowland relatives. *Darlingtoni* is undoubtedly a very localized form; it ascends to moisture-laden regions at elevations greater than those occupied by any other race of *andrewsi* so far examined, and it seems to be restricted to the heavily forested Smoky Mountain ridge and adjacent ravines in the region of Mt. Leconte. The following labels are carried by the type series: "State Road to Newfound Gap," Sevier Co.; "Tenn., 3500 ft." (type and allotype); "Newfound Gap to Clingman's Dome, Tenn.—N. C., 5000 ft." (paratype); "Bryson City," Swain Co.; "N. C., 2000 ft."

These specimens were all collected by P. J. Darlington, Jr., after whom it is a pleasure to name the subspecies.

1f. *S. andrewsi waldensis* subsp. n.

*Type*: ♂, Philadelphia Academy, H. A. Pilsbry, collector.

*Allotype*: ♀, Philadelphia Academy, H. A. Pilsbry, collector.

*Type locality*: Sawyer's Springs, Tennessee.

*Type ♂*: L. 25 mm.; W. 10.2 mm.; h. ind. 0.45; p. ind. 0.81; e. ind. 0.72; a. ind. 0.44; t. ind. 0.47. Above, rather brilliant violaceous, head blue-green-black, margins green blue; below, black, tarsi dark brown (Pl. 67, fig. 1).

*Allotype ♀*: L. 28.4 mm.; W. 10.9 mm.; h. ind. 0.42; p. ind. 0.83; e. ind. 0.70; a. ind. 0.61. Color as in type, pronotum darker, greener.

Judging by its general habitus, *waldensis* is a giant relative of *parvitarasalis*; the pronotum posterior to the lateral angles is similarly elongated and the male tarsal pad (Pl. 69, fig. 9) on the first segment is similarly reduced. The elytral striae are relatively finely and evenly punctured, there being very little costal interruption except at the extreme elytral apex. The base and margins of the pronotum are shallowly, irregularly punctate. The clytral epipleurae are more finely, regularly punctate than usual. The aedeagus is typical of the western races of *andrewsi*.

*Chorology*: All external features—size, color and sculpture, combine to place the habitat of this race in the relatively low mountains or actual piedmont. The only two specimens seen came from Walden Ridge, Hamilton Co., Tennessee, just north of Chattanooga. It is fitting that this insect should bear the name of the isolated ridge where such a unique race could have easily been evolved (Pl. 65).

## 2. *Steniridia violacea* Leconte

Often confused with various races of *andrewsi*, this species can best be identified by dissecting the genitalia of either sex (Pl. 70, fig. 2; Pl. 71, figs. 8-10). The characters of the aedeagi which separate *violacea* from *andrewsi* its nearest relative have been described in the key; they are both constant and easily recognized. Apart from this means of identification, the very much reduced plantar pad of the first segment of the male front tarsus affords the best external clue. In habitus, *violacea* differs from *andrewsi* in being shorter and more convex, in having wider, less abruptly reflexed pronotal margins, in possessing elytral

punctures which are coarser, embracing more of the walls of the costae and giving to the clytra a beaded appearance, and finally in having pronounced setigerous papillae on the humeral margins.

*Chorology:* The range of *violacea* is much that of *parvitarsalis*. However, insufficient material bearing accurate, detailed locality labels has been collected to map out the area covered by this species. From what is known of its habits, it frequents the same situations as *andrewsi*, being found in association with it at all altitudes attained by the latter.

2a. *S. violacea* s. str.

Leconte, J. L.: New Species of North American Coleoptera. Smith's Misc. Coll., vol. 6, no. 167, p. 4, 1863.

*Type:* ♂, Museum of Comparative Zoology.

*Topotype:* ♀, author's collection.

*Type locality:* "Mountains of Georgia."

*Type ♂:* L. 19.6 mm.; W. 7.8 mm.; h. ind. 0.53; p. ind. 0.73; e. ind. 0.72; a. ind. 0.47; t. ind. 0.42. Rather dark violaceous, pronotum blue with violet reflections, elytra with slight blue reflections (Pl. 67, fig. 3; Pl. 69, fig. 12).

*Topotype ♀:* L. 22.9 mm.; W. 9.4 mm.; h. ind. 0.50; p. ind. 0.73; e. ind. 0.73; a. ind. 0.46. Above, dark violaceous, slightly blue on margins, head with blue reflections; below, black, tarsi dark brown.

Two large females from the Smoky Mountains gave the following measurements: L. 22.1–23.2 mm.; W. 9.1–9.3 mm.; p. ind. 0.76; e. ind. 0.71–0.74; a. ind. 0.48. Violaceous with slight acencous reflections, margins green-blue.

*Chorology:* Although the exact locality of the type *violacea* is not known, Tray Mountain, marking the convergence of three counties (Town, White, Habersham), is centrally situated in the restricted mountainous area of north Georgia and therefore cannot be far from the true type locality. Leconte once lived in this section. The "topotype" was collected by molasses trap in September on the summit of Tray Mt. (4400 ft.) on a rocky slope among small oaks and chestnuts (Pl. 65).

The Smoky Mountains specimens (Bryson City, Swain Co., N. C., 2000 ft., Darlington) possibly represent a new race. This, however, cannot be determined until males are taken (Pl. 65).

2b. *S. andrewsi violacea caroliniae* subsp. n.

*Type:* ♂, U. S. National Museum. G. Beyer, collector.

*Allotype:* ♀, U. S. National Museum.

*Paratypes*: 4♂'s, U. S. National Museum, American Museum, Philadelphia Academy; 4♀'s, U. S. National Museum, American Museum, Philadelphia Academy.

*Type locality*: "Blue Ridge Mts., N. C."

*Type ♂*: L. 21.2 mm.; W. 5.75 mm.; h. ind. 0.47; p. ind. 0.91; e. ind. 0.73; a. ind. 0.51; t. ind. 0.47. Violaceous-black above, tarsi dark brown (Pl. 67, fig. 4).

*Allotype ♀*: L. 23.4 mm.; W. 9.6 mm.; h. ind. 0.49; p. ind. 0.77; e. ind. 0.74; a. ind. 0.49. Color as in type.

*Paratypes*: 4♂'s: p. ind. 0.71–0.74; e. ind. 0.72–0.74; a. ind. 0.46–0.49; t. ind. 0.40–0.48. Violaceous-black with dark green reflections on the margins and sometimes on the disc (Pl. 69, fig. 13).

4♀'s: p. ind. 0.73–0.74; e. ind. 0.70–0.74; a. ind. 0.46–0.50. Violaceous-black with slight green reflections on disc.

*Carolinae* is a race fairly distinct from the type in being darker, and in having more coarsely and irregularly punctate striae. The costae are interrupted marginally and discally as well as apically. The aedeagus differs slightly, the median lobe being more arcuate and the transfer piece having apically converging walls (Pl. 71, figs. 9–10).

*Chorology*: Gustav Beyer collected quite a large series of this form. His label—"Blue Ridge Mts., N. C.", is too embracing to allow of definite type locality determination. However, since Beutenmüller, who collected extensively in the Black Mts., and other collectors failed to find *violacea* there it is reasonable to suppose that this northern portion of the Blue Ridge does not contain it. Therefore the few specimens of Beyer's collecting labeled "Black Mts., N. C." are probably erroneously tagged. These have not been included in the type series; neither have those marked simply "N. C." The type locality has been tentatively placed in Transylvania Co., N. C., in the southern Blue Ridge where one would expect the range of *violacea* to extend (Pl. 65).

### 3. *Steniridia aeneicollis* Beutenmüller

Beutenmüller, Wm.: Notes on Black Mt. Beetles. Bull. Am. Mus. Nat. Hist., vol. 19, p. 515, 1903.

*Electotype*: ♂, American Museum of Natural History. Beutenmüller, collector.

*Electo-allotype*: ♀, American Museum of Natural History. Beutenmüller, collector.

*Paratypes (cotypes)*: 7♂'s, American Museum of Natural History; 3♂'s, 1♀, U. S. National Museum. Beutenmüller, collector.

*Type locality*: "Mt. Mitchell, North Carolina (Pl. 65)."

*Electotype ♂*: L. 21.4 mm.; W. 8.4 mm.; h. ind. 0.43; p. ind. 0.81; e. ind. 0.72; a. ind. 0.43; t. ind. 0.75. Above, green-black; below, black, tarsi dark brown, clytral epipleurae purple-black (Pl. 67, fig. 6).

*Electo-allotype ♀*: L. 23.5 mm.; W. 9.2 mm.; p. ind. 0.85; e. ind. 0.74; a. ind. 0.47. Color as in type.

*Paratypes*: 4♂'s: p. ind. 0.82–0.88; e. ind. 0.65–0.71; a. ind. 0.42–0.47; t. ind. 0.70–0.82. Green-black with faint violaceous reflections.

4♀'s: p. ind. 0.80–0.83; e. ind. 0.67–0.71; a. ind. 0.43–0.47. Green-black often with faint violaceous reflections; occasionally violaceous black with greenish margins.

*Aeneicollis* is not a high altitude variety of *andrewsi* as Roeschke and others have treated it but it is a distinct species with very characteristic male genitalia (Pl. 71, figs. 1–5). It is easily distinguished by its dark coloration, by its very much constricted straight-sided, top-shaped pronotum, by its irregular elytral sculpture, interrupting the costae everywhere excepting on the central discal area, and by its reduced humeri. The elytral epipleurae are coarsely, rugosely punctured. The male front tarsi, however, resemble those of *andrewsi montana* (Pl. 69, fig. 14), though the first plantar pad is relatively short.

*Chorology*: The author has seen specimens only from the Black Mountains, a high range in central western North Carolina situated north of the French Broad River. The species is typical of the spruce forests near and on the summits (5000–6500 ft.) of the highest mountains. Its almost black coloration and irregularity of sculpture reflect this choice of habitat. The following records are represented by specimens seen and dissected by the author: "Mt. Mitchell," Buncombe and Yancey Cos.; "N. C. mountain summits" (type series); Black Mts., N. C. (more inclusive term for same region); High Hickory Mt., Swannanoa, Buncombe Co., N. C. (3000 ft.). Records from the Balsam Mts., Madison Co., N. C., have not been verified but probably refer to *tricarinata*, a related species.

*Synonymy*: The name *purpurata*, applied by Beutenmüller (1918) to more purplish specimens does not seem to the author to carry sufficient analytical value to justify even varietal recognition. More or less green or purple specimens occur together.

#### 4. S. *tricarinata* Casey

Casey, T. L.: Mem. Coleop., vol. 5, p. 25, 1914.

*Type*: ♂, U. S. National Museum. Beutenmüller, collector.

*Type locality*: "Blue Ridge Mts., North Carolina."

*Type ♂*: L. 20.9 mm.; W. 8.0 mm.; h. ind. 0.42; p. ind. 0.83; e. ind. 0.70; a. ind. 0.44; t. ind. 0.64. Above, metallic green-black, pronotum slightly brighter; below, black, elytral epipleurae dark brown, tarsi dark brown (Pl. 67, fig. 5).

Casey described this form as a subspecies of *aeneicollis* which latter species he recognized. *Tricarinata* however, differs so drastically from *aeneicollis* in aedeagal equipment (see key) that there is little doubt of its inability to cross with *aeneicollis* should the ranges of the two overlap (Pl. 71, figs. 6-7). Externally, these species are very similar. *Tricarinata* is well named since its most diagnostic habitus character is the presence of three carinae on each side of the elytral suture which represent the modification of three homologous costae (the fourth, eighth and twelfth) slightly elevated in the humeral region of *aeneicollis*. In *tricarinata*, these costae extend as carinae to converge near the elytral apex of each elytron and to continue as one conspicuous ridge to the actual apex. The elytral punctures are even coarser and more irregular than in *aeneicollis* leaving intact a still smaller discal and antero-lateral area of costae. Also the elytral epipleurae are still more coarsely punctate. The humeri, especially in the male, are more reduced. All these are characters of degree rather than kind. However, a conspicuous flattening of the pronotal disc which is transversely rugose, and a similar flattening especially evident in males, of the elytra between the humeri is typical and diagnostic of *tricarinata*. The male front tarsi resemble those of *aeneicollis* (Pl. 69, fig. 15).

A selection of specimens representing the extremes in size and color of a large series from near the probable type locality have the following characteristics: 4♂'s: L. 19.8-22.8 mm.; W. 7.7-8.4 mm.; p. ind. 0.76-0.82; e. ind. 0.68-0.71; a. ind. 0.43-0.49; t. ind. 0.62-0.73. Green-black sometimes rather brilliant, often with slight violaceous reflections. 4♀'s: L. 22.8-25.6 mm.; W. 8.9-9.6 mm.; p. ind. 0.77-0.84; e. ind. 0.65-0.71; a. ind. 0.44-0.51. Green-black often with slight violaceous reflections to the less usual violet-black with green-black disc.

*Chorology*: This is another high altitude species occurring, so far as the author's records show, only in the high Smoky Mountains along the North Carolina-Tennessee border from the Little Tennessee River on the south to the Big Pigeon River on the north. Restricted for the most part to its lofty habitat in the spruce forests, above 4500 ft., the species has had no opportunity, since acquiring this habitat, of crossing the river valleys and hybridizing with *aeneicollis* its nearest relative.

The two species, both mountain-top-bound, represent true isolation products.

Of the many mountain ranges to which "Blue Ridge Mts., N. C." might refer, the author has chosen the Smoky Mountains to represent the type locality until evidence appears that this species occurs in the more easterly ranges. One thing is certain—it has never been taken in the Black Mountains and therefore presumably does not occur north of the French Broad River. The Nantahala Range of the southern Blue Ridge, however, might contain it; the records of *aeneicollis* (Wenzel collection) from the "Balsam Mountains" probably refer to *tricarinata* or to one of its possible races.

The following authenticated records are before the author: Forney Creek, Swain Co., Smoky Mts., N. C., Bradley and Knorr; Newfound Gap, Smoky Mts., Swain Co., N. C., and Sevier Co., Tenn., Darlington; Mt. Guyot, Swain Co., Smoky Mts., N. C., Barksdale.

### 5. *S. guyoti* Leconte

Leconte, J. L.: Addit. to Coleop. Fauna of U. S. Proc. Phil. Acad., p. 363, 1866.

*Type* ♀ : Museum of Comparative Zoology.

*Type locality*: "Black Mountains, North Carolina" (Pl. 65).

*Type* ♀ : L. 31.2 mm.; W. 12.8 mm.; h. ind. 0.41; p. ind. 0.85; e. ind. 0.73; a. ind. (impossible to measure because of shrunken state of specimen due to immaturity). Head and pronotum green-black, elytra aeneous with slight violaceous reflections (the extreme bronzing is due to immaturity).

This is the largest and most variable (especially as to pronotal margins) species of *Steniridida*. It is easily distinguished from the others by its relatively large, convex elytra and by its front tarsi which, in the male, are very narrow and equipped with a much reduced pad on the first segment (Pl. 69, fig. 10). The aedeagus is very characteristic (see key); it serves to separate the species from the rest of *Steniridida* and is a much more constant character than external habitus (Pl. 72, figs. 1-3). The pronotal punctures completely encircle the disc and often are mingled with coarse, irregular, transverse rugosities. The humeri are as distinct as in *andrewsi montana*. The fifth, sixth, and seventh costae and ninth, tenth, and eleventh are merged, to a greater or lesser extent, by confluence and irregular striational punctuation, over the apical two thirds of the elytra. As in *aeneicollis* and *tricarinata*,

the striae of the apical fourth of the elytra are completely obliterated by irregular punctures leaving only an embossed apical carina (the combined fourth and eighth costae).

The following are typical of *guyoti*:

*Pennington Gap, Va.*: ♀: L. 29.5 mm.; W. 12.0 mm.; p. ind. 0.80; e. ind. 0.70; a. ind. 0.44. Violaceous-black with aeneous reflections.

*Nantahala Mts., N. C.*: ♂: L. 26.6 mm.; W. 10.8 mm.; p. ind. 0.75; e. ind. 0.71; a. ind. 0.44; t. ind. 0.24. Green-black, wide marginal area slightly violaceous (Pl. 68, fig. 1).

*Mt. Sterling, N. C.*: ♀: L. 28 mm.; W. 11.7 mm.; p. ind. 0.85; e. ind. 0.74; a. ind. 0.50. Black with faint violaceous reflections.

*Chorology*: Like the preceding two species, *guyoti* is an inhabitant of the higher altitudes frequenting heavily wooded, mountain-side ravines (3500 ft. and above) and especially the moist, mountain-top spruce forests (4000–6000 ft.) where it occurs in company with *aeneicollis* or *tricarinata*. Its dark coloration and irregular sculpturing reflect the moist, cool, shady conditions under which it lives. Because of the tendency of the insect to keep close to the summits, it is expected that further study will disclose each mountain-top colony of *guyoti* to be a distinct race. No striking evidence of raciation has been found, probably due to lack of available material. *Guyoti* seems to be uniformly variable over its wide range which includes mountains on both sides of the French Broad River—a remarkable fact, as the valley of this stream acts as a very effective barrier to other flightless, monticolous species.

The exact localities of the specimens measured are recorded below: Pennington Gap, Lee Co., Va., Hubbard and Schwartz; Mt. Sterling, Haywood Co., N. C., 4000 ft., Barksdale; Highlands, Macon Co., N. C.

*Synonymy*: 5'. *S. guyoti* var. *angelli* Beutenmüller

Beutenmüller, Wm.: Notes on *Cychrus*. Brook. Ent. Soc., vol. 13, no. 4, p. 89, 1918.

*Electotype*: ♂: American Museum of Natural History. Beutenmüller, collector.

*Type locality*: "Mt. Mitchell, Black Mts., N. C."

Darlington (1931) described *confusus* as a distinct species closely related to *guyoti* but differing in the extreme narrowness of the pronotal margin. The type locality is Newfound Gap to Clingman's Dome, Smoky Mountains. As pointed out by Van Dyke, paratypes from the Black Mountains agree perfectly with cotypes of Beutenmüller's *angelli*. It is therefore necessary to suppress the name *confusus* and design-

nate an electotype of *angelli* from the original cotype series. *Angelli* is not a species or a race—it is merely an ecological variant characterized by its longitudinal pronotum, its nearly black color and more extensive breaking up of elytral costae. The aedeagi of the two forms are identical (Pl. 72, figs. 1-3).

The variation which *guyoti* var. *angelli* exhibits is brought out in the following measurements of material selected for the purpose:

*Black Mts., N. C.:* 3♂s: L. 25-28 mm.; W. 9.9-11.1 mm.; p. ind. 0.88-0.95; e. ind. 0.70-0.73; a. ind. 0.42-0.48; t. ind. 0.28-0.32. Violaceous-black to black with very slight violaceous reflections, sometimes with a greenish sheen.

2♀s: L. 29.1-31.9 mm.; W. 12.3-13.3 mm.; p. ind. 0.83-0.89; e. ind. 0.73-0.75; a. ind. 0.46-0.50. Color as in males.

*Roan Mt., N. C.:* ♀: L. 28.8 mm.; W. 11.7 mm.; p. ind. 0.88; e. ind. 0.71; a. ind. 0.46. Green-black with faint violaceous reflections.

*Smoky Mts., N. C.:* ♂: L. 25.5 mm.; W. 10.0 mm.; p. ind. 0.90; e. ind. 0.71; a. ind. 0.47; t. ind. 0.26. Violaceous, nearly black (Pl. 68, fig. 2).

♀: L. 29.5 mm.; W. 12.7 mm.; p. ind. 0.87; e. ind. 0.76; a. ind. 0.47. Blue-green-black.

The following records refer to specimens studied: Mt. Mitchell, Black Mts., about 5000-6000 ft., Beutenmüller; Roan Mt., Mitchell Co., N. C.; Newfound Gap, Sevier Co., N. C., about 6000 ft., Darlington; Mt. Leconte, Sevier Co., Tenn., 5000 ft., Valentine.

*Chorology:* Beutenmüller considered *angelli* as a black phase of *guyoti*. Since the two definite localities (Highlands, N. C., Pennington Gap, Va.) from which broadly margined *guyoti* is known, are both in relatively low, rolling mountains, it is reasonable to suppose that the expanding margin of *guyoti* with the attendant heightening of surface refraction, is correlated with low altitude factors. Typical *guyoti* is far rarer than its narrow-necked high altitude phase, *angelli*, a fact which might be interpreted as the result of life under conditions which are not ideal. Intermediate altitudes (Mt. Sterling 4000 ft.) produce intergrades.

#### 6. *S. lodingi* sp. n.

This species is perhaps the most distinctive in the entire group *Steniridia*. Its flatness, smoothness, and wide cordate appearance make it an easy form to recognize without the necessity of dissecting genitalia. However, a considerable range of variability may lead to misinterpretation if the characters described below are too strictly applied.

The types were collected by Dr. Henry P. Löding in honor of whom the author takes great pleasure in naming the species.

*Chorology:* Brilliance of color and fineness of sculpture are, in this species, again correlated with a low altitude habitat. Rivers, not mountain ranges, were evidently followed in the distribution of *lodingi*, which possibly originated from a *ridingsi*-like ancestor on the highlands of northeastern Alabama and migrated down the Tennessee and down the tributaries of the Tombigbee and Alabama Rivers until the edges of the flood plains were reached.

6a. *S. lodingi* s. str.

*Type:* ♂, U. S. National Museum. H. P. Löding, collector.

*Paratype:* ♂, Collection of H. P. Löding.

*Type locality:* Monte Sano, Madison Co., Alabama (Pl. 65).

*Type* ♂: L. 21.8; W. 9.6 mm.; h. ind. 0.45; p. ind. 0.93; e. ind. 0.80; a. ind. 0.43; t. ind. 0.25. *Color:* above, deep rather brilliant violaceous, head and pronotum blacker, former and margins of latter as well as narrow margin of elytra with blue reflections; below, black; appendages reddish brown distally, dark brown proximally (basal four antennal segments and tibiae), femora black. The *pronotum* is cordate with very narrow, abruptly reflexed margins; anterior angles subacute, lateral angles almost obliterated, posterior angles rounded; anterior margin evenly arcuate, posterior margin slightly convex; distance from anterior angle to lateral seta 1.9 mm.; margins, basal prominences and anterior discal triangle of pronotum sparsely punctate. *Elytra* very wide with humeri much expanded giving the body a distinctly cordate appearance; disc very flat; margins relatively wide, strongly reflexed; elytral epipleurae very deep, rather evenly, profusely punctate; costae flat, uninterrupted except at extreme apical end (on disc, not further than 3.5 mm. from apex), the fourth and eighth combining to form a vague apical carina; striae evenly, rather shallowly punctate; margin with wide posterior fossae, each containing on its external wall an elongate, divided tubercle; apex produced. Front *tarsus* of male similar to that of *guyoti*, plantar pads much reduced. *Aedeagus* relatively small, with well developed transfer apparatus as described in key (Pl. 68, fig. 3; Pl. 69, fig. 11; Pl. 72, figs. 4-5).

*Paratype* ♂: L. 22.1 mm.; W. 9.0 mm.; h. ind. 0.43; p. ind. 0.95; e. ind. 0.74; a. ind. 0.38; t. ind. 0.33. Violaceous, elytra somewhat more brilliant than in type. Elytral disc flatter, humeri less pronounced than in type.

Additional specimens from Tuscaloosa, Alabama, are not included in the type series because of difference in locality. However, they are essentially identical with the types in all respects, including genitalia. Their measurements are as follows: ♂: L. 21.9 mm.; W. 6.75 mm; p. ind. 0.90; e. ind. 0.78; a. ind. 0.43; t. ind. 0.27. Dark violaceous with green reflections. ♀: L. 22.6 mm.; W. 9.7 mm.; p. ind. 0.93; e. ind. 0.78; a. ind. 0.46. Color exactly as in type.

*Chorology:* The type race of *lodingi* has been taken on both sides of the Tennessee River, the specimens from the south side coming from the valley of the Big Warrior River whose headwaters are close to the south bank of the Tennessee.

All the records available for the type race are these: Monte Sano, Madison Co., Alabama, H. P. Löding (type and paratype); Tuscaloosa, Tuscaloosa Co., Alabama, Archer, Löding and W. B. Jones.

#### 6b. *S. lodingi obscura* subsp. n.

*Type:* ♂, U. S. National Museum. H. H. Smith, collector.

*Allotype:* ♀, U. S. National Museum. H. H. Smith, collector.

*Paratypes:* 2♂s, ♀, U. S. National Museum. H. H. Smith, collector.

*Type locality:* Wadley, Randolph Co., Alabama (Pl. 65).

*Type ♂:* L. 21.0 mm.; W. 8.7 mm.; h. ind. 0.48; p. ind. 0.88; e. ind. 0.73; a. ind. 0.45; t. ind. 0.27. Head and pronotum black, elytra blue-black with violaceous reflections (Pl. 68, fig. 4).

*Allotype ♀:* L. 23.7 mm.; W. 9.5 mm.; h. ind. 0.47; p. ind. 0.93; e. ind. 0.70; a. ind. 0.43. Blue-black.

*Paratypes:* 2♂s: L. 18.6–20.4 mm.; W. 7.8–8.2 mm.; p. ind. 0.87–0.95; e. ind. 0.73–0.74; a. ind. 0.45; t. ind. 0.21–0.36. Blue and violaceous-black.

♀: L. 19.5 mm.; W. 8.5 mm.; p. ind. 0.85; e. ind. 0.77; a. ind. 0.46. Head and pronotum blue-black, elytra violaceous-black.

This is a dark race of *lodingi* which further departs from the latter in being smaller, less compressed and more normally shaped throughout. The costae are less flat and wide, the elytral punctures more evident but the pronotum, which averages more transverse, is devoid of punctuation. Tarsi and aedeagi are similar to those of type *lodingi*.

*Chorology:* Situated on the Tallapoosa River whose source is remote from the Tennessee, this colony shows indications of isolation. The dark coloration may be the result of life in low, very wet, shady situations such as are frequented by the black *Scaphinotus tenebricosus*.

### 7. *S. ridingsi* Bland

*Ridingsi* is the smallest and, phylogenetically, the most detached species in the series. The almost total absence of chitinized transfer apparatus in the aedeagus sets it apart from the other members of *Steniridia*. It is typical of piedmont *Steniridia* in exhibiting considerable metallic lustre and in having costae uninterrupted by irregular punctation. In habitus and in aedeagal equipment it suggests *lodigi*.

**Chorology:** Like the last species, *ridingsi* is evidently born of a mother stock inhabiting a high plateau country from which it migrated down the rivers whose sources lie within this mountainous, ancestral range. It is now found broken up into distinct races each occupying a river valley at relatively low altitudes. Thus the Potomac, Monongahela, and the James Rivers each support a subspecific colony some distance from their sources while the intervening Alleghenian divide represents the probable ancestral abode. A record from Tennessee (collected probably by H. A. Pilsbry) has not been investigated.

*Ridingsi* should be looked for in rocky, moist, shady, stream-side situations. Like all *Steniridia* it is most easily collected at night when it may occasionally be seen walking over the rocks. It is then readily attracted by the smell of black molasses; a little of this placed in a can sunk into the ground close to the largest boulders will almost certainly reward the collector should *Steniridia* be present at all. June, late September and early October seem to be the best times for taking *ridingsi*.

#### 7a. *S. ridingsi* s. str.

Bland, J. H. B.: Proc. Ent. Soc. Phila., vol. 1, p. 354, 1863.

**Type:** ♀, Philadelphia Academy of Sciences.

**Type locality:** Hampshire Co., Virginia (Pl. 65).

The type race is the narrowest, smoothest and most brilliantly refractive of the three. Characteristics of the colony in Fairfax Co., Virginia, are taken from the following samples: 3♂s: L. 17.7–18.2 mm.; W. 6.7–6.9 mm.; h. ind. 0.46–0.47; p. ind. 0.87–0.94; e. ind. 0.69; a. ind. 0.41–0.43; t. ind. 0.64 (Pl. 68, fig. 5); 2♀s: 18.7–19.2 mm.; W. 6.9–7.0 mm.; h. ind. 0.45–0.46; p. ind. 0.92–0.94; e. ind. 0.63–0.66; a. ind. 0.41–0.43. Color of both sexes: above, head and pronotum dark violaceous-blue with blue-green reflections, elytra rather brilliant violaceous with strong aeneous reflections; below, black, tarsi rather light yellow-brown.

**Chorology:** This race inhabits the Potomac valley where it may be

collected in the moist stream-side forest at the foot of the steep river bank where it is very rocky. The following are localities of samples studied: Great Falls and Plummer's Island, Fairfax Co., Virginia.

7b. *S. ridingsi monongahelae* Leng

Leng, Chas. W.: A new variety of *Scaphinotus*. Jour. N. Y. Ent. Soc., vol. 25, no. 1, 1917.

*Type*: ♂, collection of Chas. Leng. T. N. Brown, collector.

*Type locality*: Uniontown, Fayette Co., Pennsylvania.

*Topotypes*: 3♂s: L. 15.9-17.8 mm.; W. 6.2-7.0 mm.; p. ind. 0.80-0.89; e. ind. 0.70-0.72; a. ind. 0.42-0.45; t. ind. 0.55-0.63. Above, head blue-black, pronotum and elytra violaceous, often with green-blue reflections, pronotum darker (Pl. 68, fig. 6). 3♀s: L. 18.4-20.5 mm.; W. 7.2-8.2 mm.; p. ind. 0.87-0.89; e. ind. 0.70-0.71; a. ind. 0.42-0.44. Green-blue-black, elytra usually with violaceous reflections.

This is a distinct race differing from typical *ridingsi* in being broader throughout especially as to pronotal margins, in being flatter discally with impressed suture and in having more prominent humeri and coarser elytral punctures. It also tends to be darker in coloration.

*Chorology*: As Mr. Leng points out, this form inhabits the "Monongahela valleys west of the mountains." The author, however, has seen only topotype material from Uniontown.

*Synonymy*: Casey's (1920) *tenuiceps* which he described as a new species is a mere variant of *monongahelae*. The pronotum is slightly more elongate and the male front tarsi slightly narrower than usual. The aedeagi of the two forms are identical. As *tenuiceps* comes from Uniontown, the author has taken the liberty of including Casey's type male and the female paratype in his measured series of topotypes of *monongahelae*.

7c. *S. ridingsi intermedia* subsp. n.

*Type*: ♂, Museum of Comparative Zoology. Darlington, collector.

*Type locality*: Natural Bridge, Rockbridge Co., Virginia. (Pl. 65).

*Type ♂*: L. 15.6 mm.; W. 6.1 mm.; h. ind. 0.47; p. ind. 0.91; e. ind. 0.72; a. ind. 0.43; t. ind. 0.50. Above, head green-black, pronotum blue-green-black with violaceous reflections, elytra dark violaceous with blue-green reflections on margins; below, black, tarsi rather bright yellowish brown.

This specimen, the only one seen, agrees with typical *ridingsi* in having a relatively elongate pronotum with narrow margins. However, the sides are more rounded than in *ridingsi* from Fairfax Co. It agrees with race *monongahelae* in possessing relatively coarse elytral punctation and in the elytral disc which is flattened and depressed along the suture. The humeri, however, are more prominent than in the six topotypes of *monongahelae* before the author. The plantar pads of the first segment of the male's front tarsi are slightly less extensive than in either of the other two races. The aedeagus seems to be identical with *monongahelae*.

*Chorology:* This may be an isolated race living only in the valley of the James River.

#### CONCLUSIONS

1. The male genitalia (acdeagi), and probably also the female genital structures, afford a reliable key to an analysis of the forms of *Steniridia*, a group of highly variable species.
2. The original source of dispersed *Steniridia* colonies is probably the medium-high (above 2000 ft.) Allegheny plateau.
3. Speciation in *Steniridia* is clearly correlated with isolation. The latter may proceed as a result of either:
  - a. The ascent of high mountains to their summits where adjustments are made to special conditions and from which migration is impossible without encountering other, less congenial conditions lower down, or
  - b. The descent from the plateau into the river valleys where conditions are not vastly different from the ancestral environment but from which escape is impossible without the necessity of crossing dry hills and ridges.
4. The first process produces genetically distinct species (*acencicollis*, *tricarinata*); the second tends to evolve races or subspecies (forms of *andrewsi*, *ridingsi*, etc.).
5. Habitus characters and ecological conditions can be correlated in *Steniridia*: the blacker, greener forms more unstable as to contour and with irregular, vermiculate sculpture dwell in the highest cloud-forests; in contrast, stronger color refraction and finer, regular sculpture characterize populations inhabiting the valleys.

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CHAPEL HILL, N. C.

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## EXPLANATION OF PLATES 65-73

## PLATE 65

*Localities of Steniridida*

1. *Scaphinotus Steniridida ridingsi* Bland.
  - a. *monongahelae* Leng. Type locality: Uniontown, Fayette Co., Pennsylvania.
  - b. s. str. Type locality: Hampshire Co., Virginia; Great Falls, Fairfax Co., Virginia.
  - c. *intermedia* subsp. n. Type locality: Natural Bridge, Rockbridge Co., Virginia.
2. *Scaphinotus Steniridida andrewsi* Harr.
  - a. s. str. Neotype locality: Chapel Hill, Orange Co., North Carolina; type locality, "North Carolina."
  - b. *germari* Chd. Type locality: Claiborne Co. (?), "Tennessee"; Pennington Gap, Lee Co., Virginia, and Pine Mountain, Harlan Co., Kentucky; Corbin, Whitley Co., Kentucky; Frankfort, Franklin Co., Kentucky; Cincinnati, Hamilton Co., Ohio; Gawley Mt., Fayette Co., West Virginia; Fairmont, Marion Co., West Virginia; Uniontown, Fayette Co., Penn.
  - b'. *germari* Chd. Close to *andrewsi montana*. Mountain Lake, Giles Co., Virginia.

- c. *montana* subsp. n. Type locality: Beech Mt., Avery Co., North Carolina; Grandfather Mountain, Avery Co., North Carolina.
- c'. *montana* subsp. n. Close to *parvitarsalis* subsp. n. Mt. Guyot, Haywood Co., North Carolina.
- d. *darlingtoni* subsp. n. Type locality: Newfound Gap, Sevier Co., Tennessee.
- e. *parvitarsalis* subsp. n. Type locality: Clayton, Rabun Co., Georgia; Grimshawes, Jackson Co., North Carolina; Unaka Mts., Monroe Co., Tennessee.
- f. *waldensis* subsp. n. Type locality: Sawyer's Springs, Hamilton Co., Tennessee.
- 3. *Scaphinotus Steniridia aeneicollis* Beut. Type locality: Mt. Mitchell (high altitude), Buncombe and Yancey Cos., North Carolina.
- 4. *Scaphinotus Steniridia tricarinata* Casey. Type locality: "Blue Ridge Mts., North Carolina," in all probability refers to Smoky Mts., North Carolina.
- 5. *Scaphinotus Steniridia violacea* Lec.
  - a. *carolinac* subsp. n. Type locality: "Blue Ridge Mts., N. C.," Transylvania Co. (?), North Carolina.
  - b. s. str. Type locality: "Mts. of Georgia," Towns and White Cos. (?), Georgia; Bryson City, Swain Co., North Carolina.
- 6. *Scaphinotus Steniridia guyoti* Lec. Type locality: "Black Mts." Buncombe and Yancey Cos., North Carolina; Highlands, Macon Co., North Carolina; Smoky Mts., North Carolina—Tennessee; Pennington Gap, Lee Co., Virginia.
- 7. *Scaphinotus Steniridia lodingi* sp. n.
  - a. *obscura* subsp. n. Type locality: Wadley, Randolph Co., Alabama.
  - b. s. str. Type locality: Monte Sano, Madison Co., Alabama; Tuscaloosa, Tuscaloosa Co., Alabama.

## PLATE 66

(3.3X)

Explanation: A. M. N. H.—American Museum of Natural History, New York City; J. M. V.—author's collection; M. C. Z.—Museum of Comparative Zoology, Cambridge, Mass.; P. A. S.—Philadelphia Academy of Sciences, Philadelphia, Pa.; U. S. N. M.—United States National Museum, Washington, D. C.

- Fig. 1. *Scaphinotus Steniridia andrewsi montana* subsp. n. Type ♂. Beech Mt., Avery Co., North Carolina. U. S. N. M.
- Fig. 2. *Scaphinotus Steniridia andrewsi* var. *amplicollis* Casey. Type ♂. Black Mts., Buncombe and Yancey Cos., North Carolina. U. S. N. M.
- Fig. 3. *Scaphinotus Steniridia andrewsi parvitaralis* subsp. n. Paratype ♂. Clayton, Rabun Co., Georgia. P. A. S.
- Fig. 4. *Scaphinotus Steniridia andrewsi darlingtoni* subsp. n. Type ♂. Newfound Gap, Smoky Mts., Sevier Co., Tennessee. M. C. Z.
- Fig. 5. *Scaphinotus Steniridia germari* Chd. close to *andrewsi* Harr. ♂. Mountain Lake, Giles Co., Virginia. M. C. Z.
- Fig. 6. *Scaphinotus Steniridia andrewsi germari* Chd. ♂. Uniontown, Fayette Co., Pennsylvania. J. M. V.

## PLATE 67

(3.3X)

For explanation see Plate 66.

- Fig. 1. *Scaphinotus Steniridia andrewsi waldensia* subsp. n. Type ♂. Sawyer's Springs, Hamilton Co., Tennessee. P. A. S.
- Fig. 2. *Scaphinotus Steniridia andrewsi* s. str. Neototype ♂. Chapel Hill, Orange Co., North Carolina. U. S. N. M.
- Fig. 3. *Scaphinotus Steniridia violacea* Lee. Type ♂. "Mts. of Georgia." M. C. Z.
- Fig. 4. *Scaphinotus Steniridia violacea carolinae* subsp. n. Type ♂. "Blue Ridge Mts., North Carolina." U. S. N. M.
- Fig. 5. *Scaphinotus Steniridia tricarinata* Casey. Type ♂. "Blue Ridge Mts., North Carolina." U. S. N. M.
- Fig. 6. *Scaphinotus Steniridia aenicollis* Beut. Type ♂. Mt. Mitchell, Black Mts., Buncombe Co., North Carolina. A. M. N. H.

## PLATE 68

(3.3X)

For explanation see Plate 66.

- Fig. 1. *Scaphinotus Steniridia guyoti* Lee. ♂. Highlands, Macon Co., North Carolina. M. C. Z.
- Fig. 2. *Scaphinotus Steniridia guyoti* var. *angelli* Beut. ♂. "Newfound Gap to Clingman's Dome, Smoky Mts., North Carolina, Tennessee." M. C. Z.
- Fig. 3. *Scaphinotus Steniridia lodingi* sp. n. Type ♂. Monte Sano, Madison Co., Alabama. U. S. N. M.
- Fig. 4. *Scaphinotus Steniridia lodingi obscura* subsp. n. Type ♂. Wadley, Randolph Co., Alabama. U. S. N. M.
- Fig. 5. *Scaphinotus Steniridia ridingsi* Bland. ♂. Great Falls, Fairfax Co., Virginia. J. M. V.
- Fig. 6. *Scaphinotus Steniridia ridingsi monongahelae* Leng. Topotype ♂. Uniontown, Fayette Co., Pennsylvania. J. M. V.

## PLATE 69

Right front tarsi (fig. 9 left front tarsus) of male *Steniridia* (1.5X).

1. *Scaphinotus Steniridia andrewsi montana* subsp. n. Beech Mt., Avery Co., North Carolina.
2. *Scaphinotus Steniridia andrewsi germari* Chd. Ohio (southern).
3. *Scaphinotus Steniridia andrewsi* Harr. s. str. Neototype. Chapel Hill, Orange Co., North Carolina.
4. *Scaphinotus Steniridia andrewsi parvitarsalis* subsp. n. Unaka Mts., Monroe Co., Tennessee.
5. *Scaphinotus Steniridia andrewsi parvitaralis* subsp. n. Paratype. Rabun Co., Georgia.
6. *Scaphinotus Steniridia andrewsi parvitarsalis* subsp. n. Grimshawes, Jackson Co., North Carolina.

7. *Scaphinotus Steniridia andrewsi montana* close to *parvitarsalis* subsp. n. Mt. Guyot, Swain Co., North Carolina.
8. *Scaphinotus Steniridia andrewsi darlingtoni* subsp. n. Paratype. Clingman's Dome, Swain Co., North Carolina.
9. *Scaphinotus Steniridia andrewsi waldensia* subsp. n. Type. Sawyer's Springs, Hamilton Co., Tennessee.
10. *Scaphinotus Steniridia guyoti* Lec. Highlands, Macon Co., North Carolina.
11. *Scaphinotus Steniridia lodingi* sp. n. Type. Monte Sano, Madison Co., Alabama.
12. *Scaphinotus Steniridia violacea* Lec. Type. "Mountains of Georgia."
13. *Scaphinotus Steniridia violacea caroliniae* subsp. n. Paratype. "Blue Ridge Mts., North Carolina."
14. *Scaphinotus Steniridia aenecicollis* Beut. High Hickory Mt., Buncombe Co., North Carolina.
15. *Scaphinotus Steniridia tricarinata* Casey. Forney Creek, Swain Co., North Carolina.
16. *Scaphinotus Steniridia ridingsi* Bland. Great Falls, Fairfax Co., Virginia.

#### PLATE 70

Dissections of the vaginal cavities of three species of *Steniridia*, ventral aspect, with the ventral vaginal wall thrown to the left side.

Fig. 1. *Scaphinotus Steniridia andrewsi parvitarsalis*, subsp. n. Paratype. Mountain City, Rabun Co., Georgia. *a*—right style; *b*—right basal plate (coxite) with internal spicule; *c*—sternite (valvifer), probably ninth; *d*—ninth tergite; *e*—vaginal cavity, *e'* its external orifice (vulva); *f*—oviduct at the point of bifurcation, *f'* its orifice on the mid ventral line; *g*—annulus; *h*—chitinized plate; *i*—chitinized valvular spicule on posterior wall of common oviduct; *j*—gland?, *j'* its orifice; *k*—chitinized plate on dorsal wall of vaginal orifice.

Fig. 1a. Internal view of a portion of the ventral vaginal wall lettered as above.

Fig. 2. *Scaphinotus Steniridia violacea* Lec. Topotype. Tray Mt., Towns Co., Georgia.

Fig. 3. *Scaphinotus Steniridia tricarinata* Casey. Smoky Mts., North Carolina.

#### PLATE 71

Aedeagi of *Steniridia*, dorsal and right lateral views (10X) (as oriented in situ within the male) with details of the transfer apparatus (15X); in dorsal aspect (arcuate figures), the median lobe and one or both of its lateral appendages (parameres) are shown; in right lateral aspect (straight figures) the parameres have been omitted; in both views, the internal sclerotizations appear as dark masses showing through the walls of the median lobe.

Legend (for plates 71-73): *a*—transfer apparatus seen from the left (as though through concave wall of median lobe); *b*—cross section of same at zone indicated by a line on *a*; *c*—dorsal aspect of transfer apparatus; *d*—transfer apparatus seen from the right (as though through convex wall of median lobe).

Fig. 1. *Scaphinotus Steniridia aeneicollis* Beut. "Cotype." Mt. Mitchell, Black Mts., N. C. Left lateral aspect (ventral in copula position) in plane of diagonal line through fig. 3, showing the distended internal sac with its apical transfer apparatus and more proximal sclerotized folds.

Fig. 2. Enlarged detailed view of one of the paired, sclerotized folds partially opened.

Fig. 3. Dorsal aspect of the same aedeagus showing both parameres.

Fig. 4. *Scaphinotus Steniridia aeneicollis* Beut. High Hickory Mt., Buncombe Co., North Carolina.

Fig. 5. *Scaphinotus Steniridia aeneicollis* Beut. Same specimen.

Fig. 6. *Scaphinotus Steniridia tricarinata* Casey. Forney Creek, Swain Co., North Carolina.

Fig. 7. *Scaphinotus Steniridia tricarinata* Casey. Same specimen.

Fig. 8. *Scaphinotus Steniridia violacea* Lec. Type. "Mts. of Georgia."

Fig. 9. *Scaphinotus Steniridia violacea carolinac* subsp. n. Paratype. "Blue Ridge Mts., North Carolina."

Fig. 10. *Scaphinotus Steniridia violacea carolinae* subsp. n. Same specimen.

#### PLATE 72

Aedeagi of *Steniridia* (continued); for explanation see legend of Plate 71.

Fig. 1. *Scaphinotus Steniridia guyoti* var. *angelli* Beut. Clingman's Dome, Smoky Mts., North Carolina-Tennessee.

Fig. 2. *Scaphinotus Steniridia guyoti* var. *angelli*. Same specimen.

Fig. 3. *Scaphinotus Steniridia guyoti* Lec. Highlands, Jackson Co., North Carolina.

Fig. 4. *Scaphinotus Steniridia lodingi* sp. n. Type. Monte Sano, Madison Co., Alabama. Transfer apparatus from specimen from Tuscaloosa, Alabama.

Fig. 5. *Scaphinotus Steniridia lodingi* sp. n. Same specimen (type).

Fig. 6. *Scaphinotus Steniridia ridingsi* Bland. Great Falls, Fairfax Co., Virginia.

Fig. 7. *Scaphinotus Steniridia ridingsi* Bland. Same specimen.

Fig. 8. *Scaphinotus Steniridia ridingsi monongahelae* Leng. Topotype. Uniontown, Pennsylvania.

Fig. 9. *Scaphinotus Steniridia andrewsi montana* subsp. n. Type. Beech Mt., Avery Co., North Carolina.

#### PLATE 73

Aedeagi of *Steniridia* (continued); for explanation see legend of plate 71.

Fig. 1. *Scaphinotus Steniridia andrewsi* var. *amplicollis* Casey. Type. "Black Mts., North Carolina."

Fig. 2. *Scaphinotus Steniridia andrewsi germari* Chd. Uniontown, Fayette Co., Pennsylvania.

Fig. 3. *Scaphinotus Steniridia andrewsi germari* Chd. Hamilton Co., Ohio.

Fig. 4. *Scaphinotus Steniridia andrewsi montana* close to *germari* Chd. Mountain Lake, Giles Co., Virginia.

Fig. 5. *Scaphinotus Steniridia andrewsi germari* Chd. close to typical *andrewsi montana* subsp. n. Mountain Lake, Giles Co., Virginia.

Fig. 6. *Scaphinotus Steniridia andrewsi* s. str. Neototype. Chapel Hill, Orange Co., North Carolina.

Fig. 7. *Scaphinotus Steniridia andrewsi* s. str. Neototype. Same specimen.

Fig. 8. *Scaphinotus Steniridia andrewsi parvitalis* subsp. n. Paratype. Clayton, Rabun Co., Georgia.

Fig. 9. *Scaphinotus Steniridia andrewsi parvitalis* subsp. n. Unaka Mts., Monroe Co., Tennessee.



PLATE 65

LEGEND

- definite locality
- ◊ indefinite "
- × type "

elevation:

■	1000 - 2000 ft.
▨	2000 - 4000 ft.
▨	4000 - 5000 ft.
▨	5000 - 6000 ft.

500 ft line

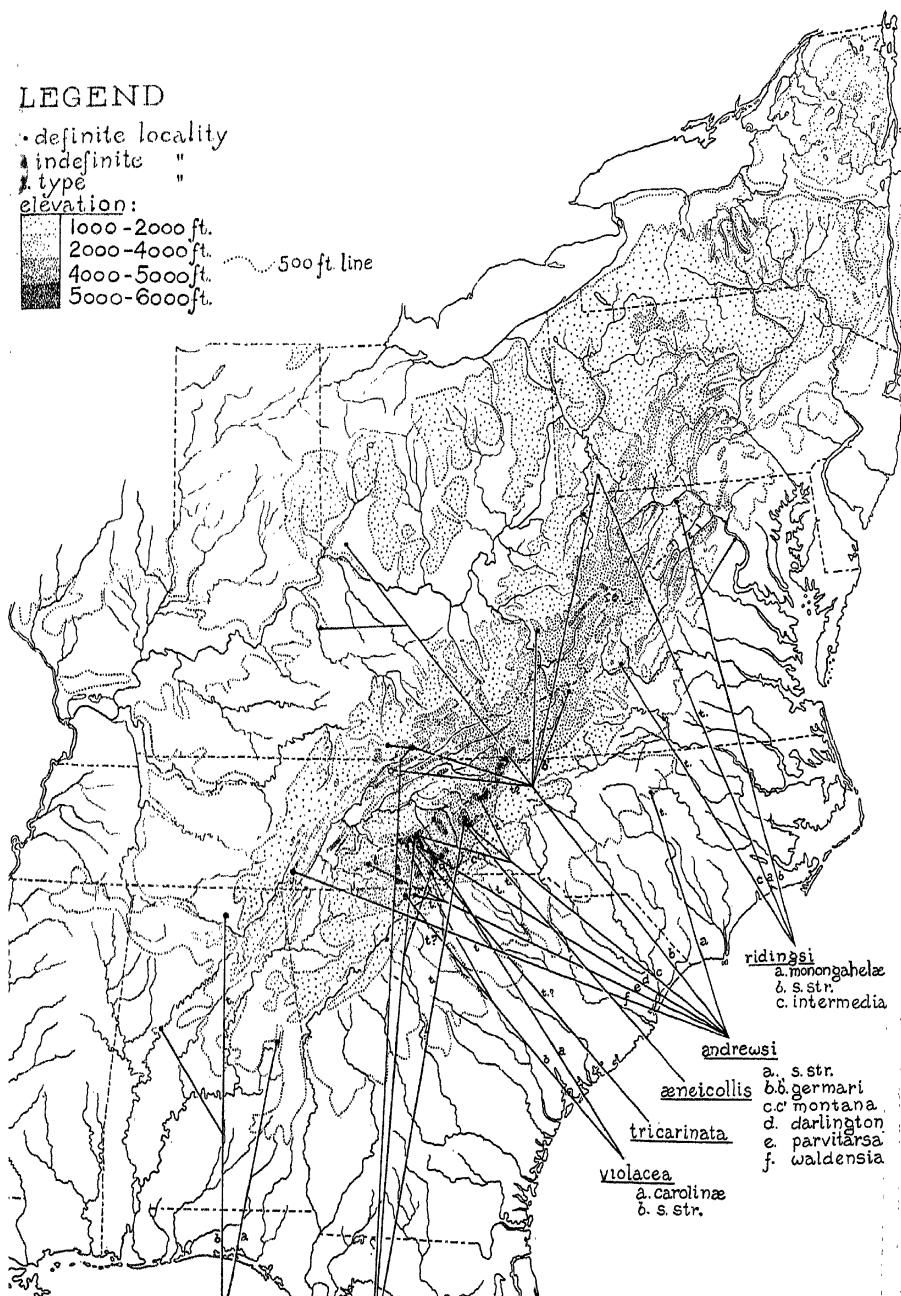




PLATE 66

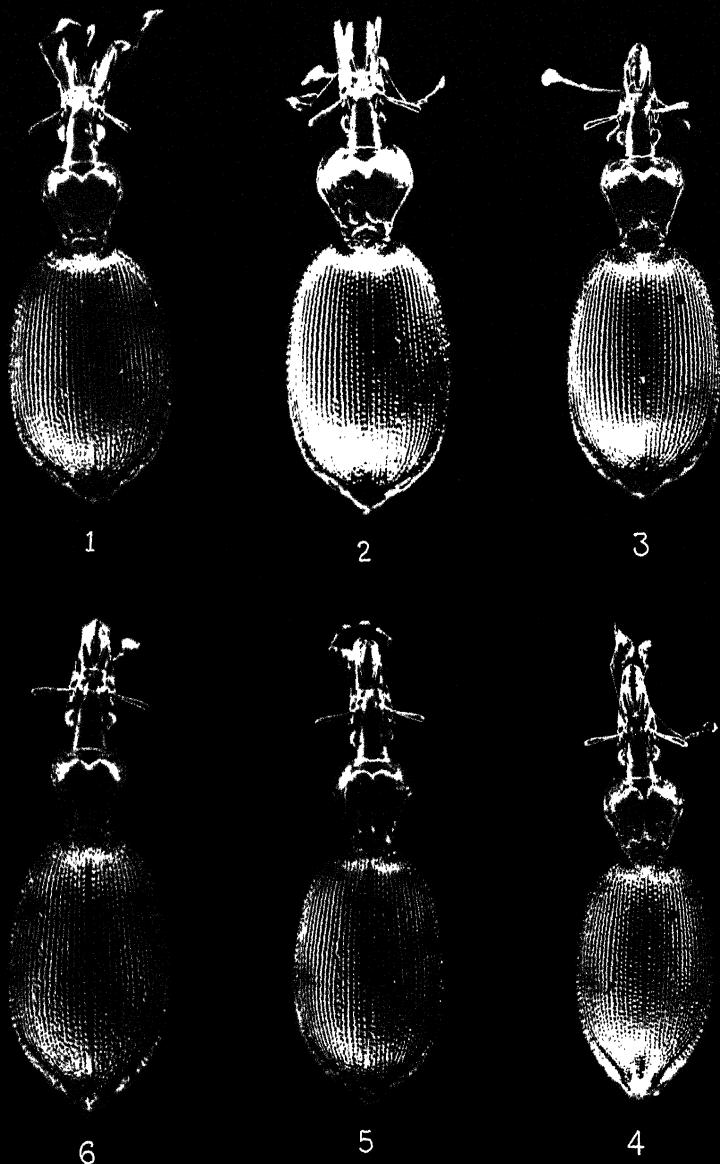




PLATE 67

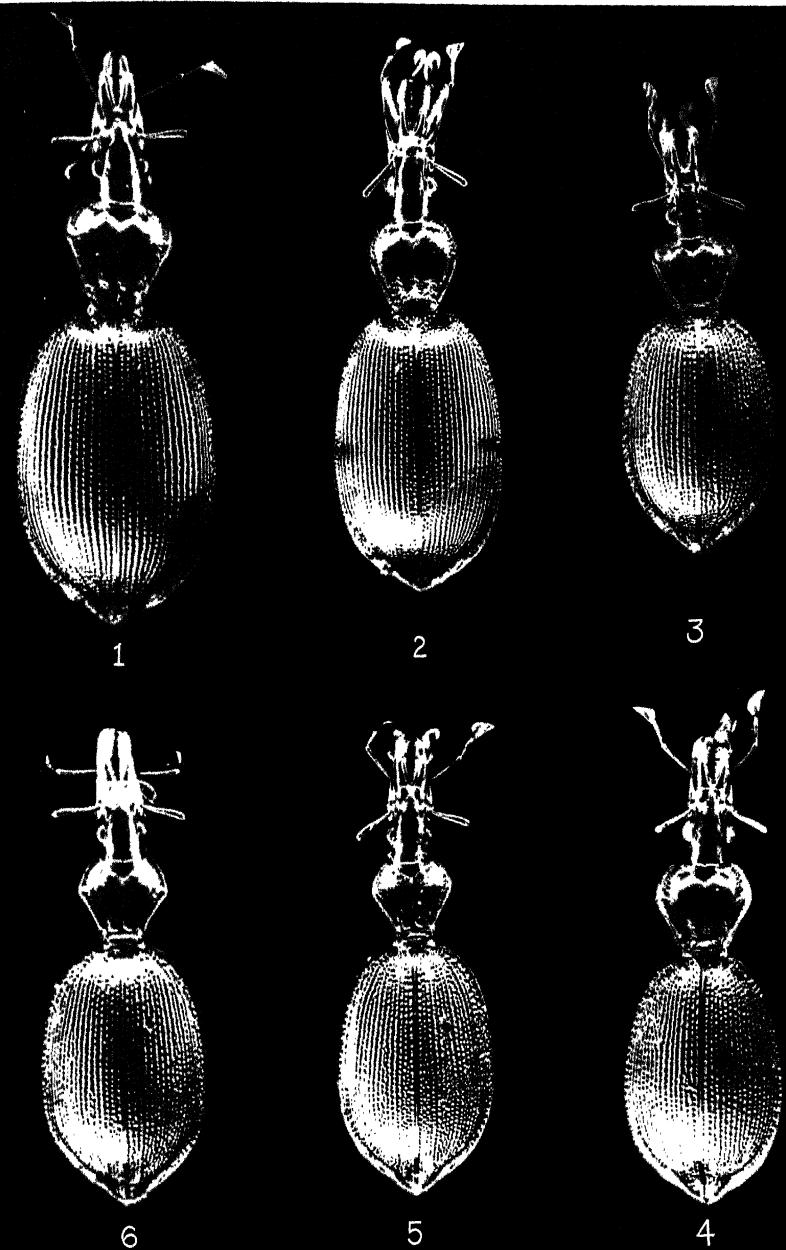




PLATE 68

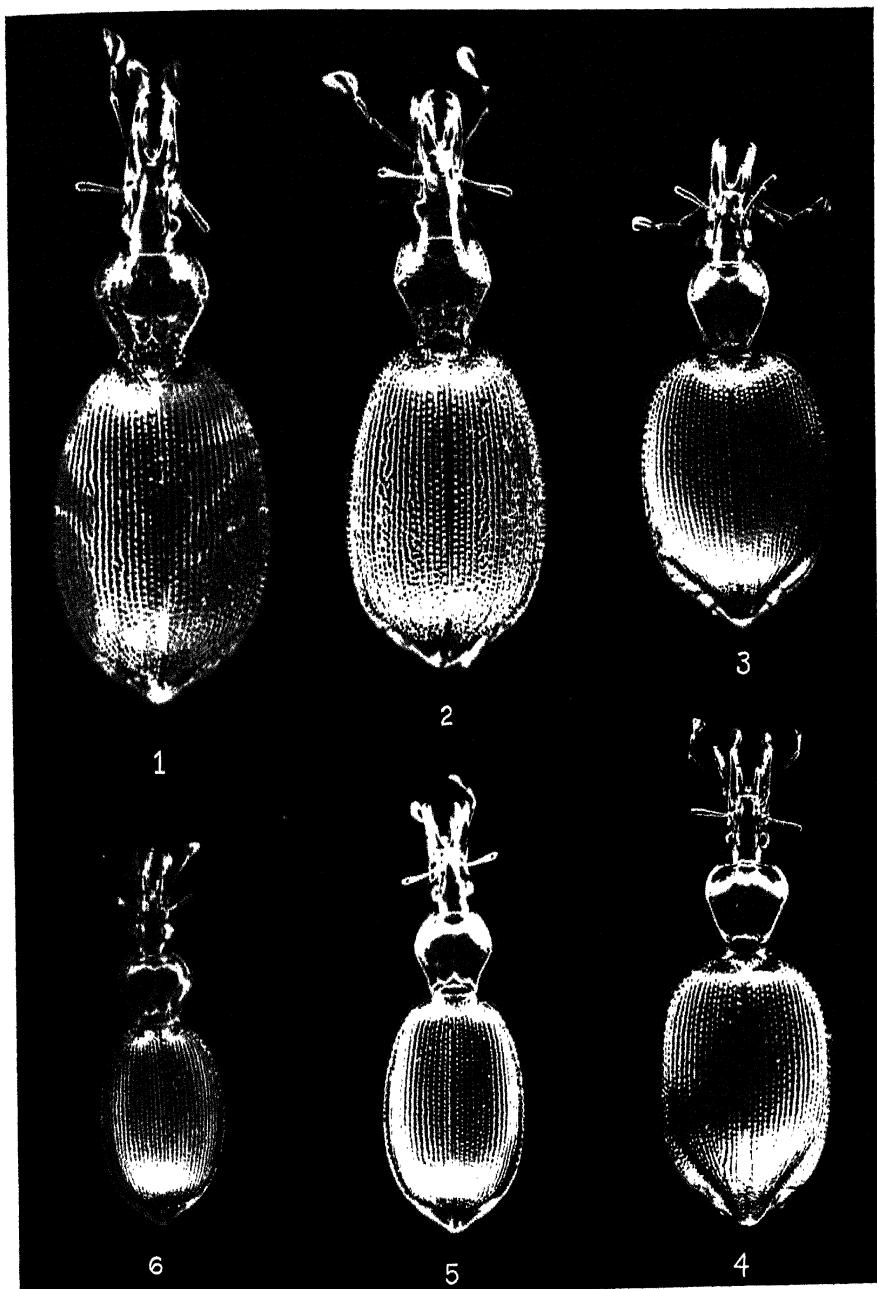
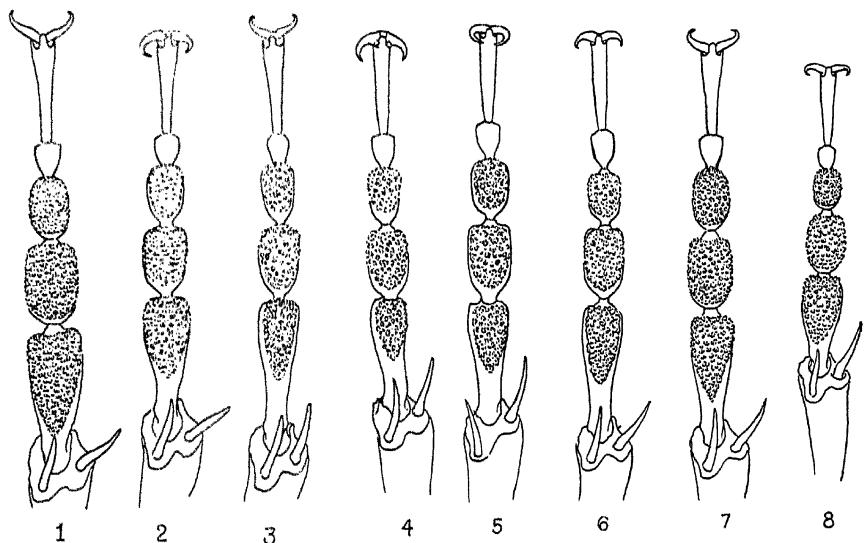
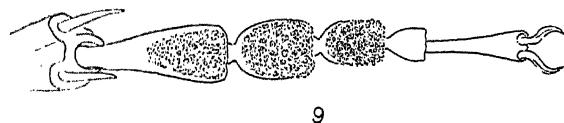




PLATE 69



1 2 3 4 5 6 7 8



9

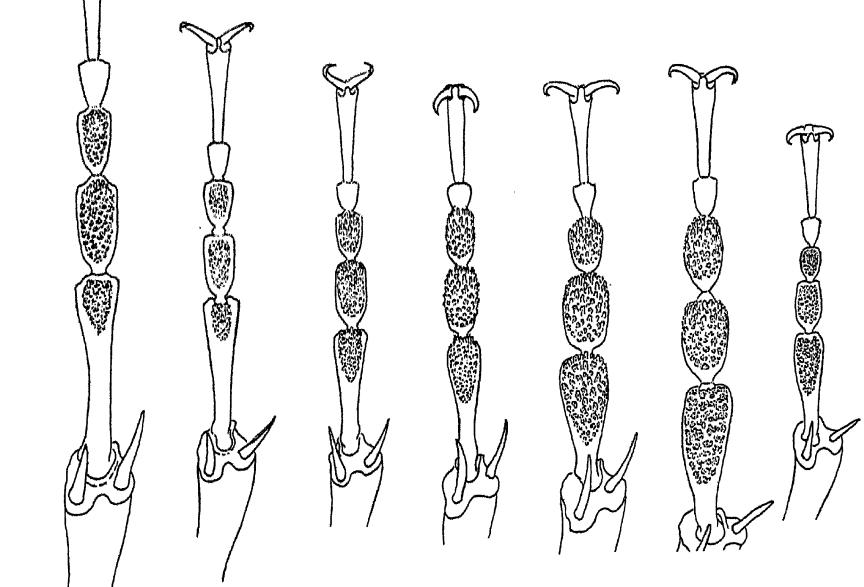




PLATE 70

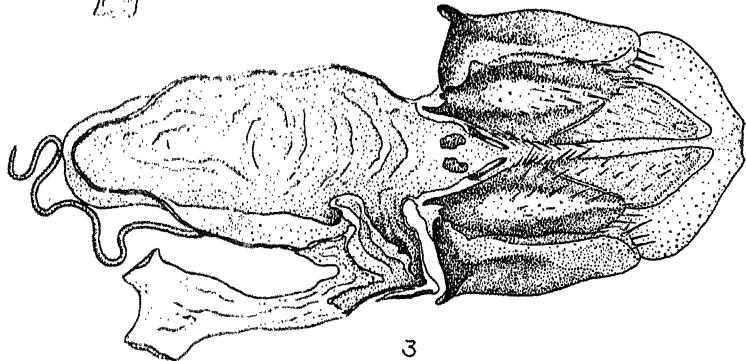
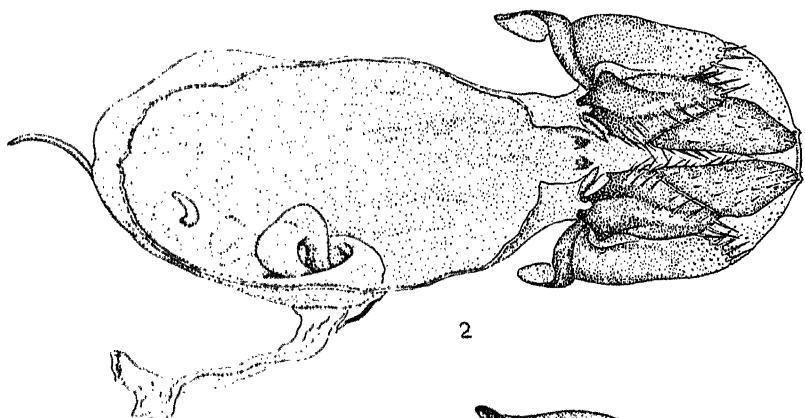
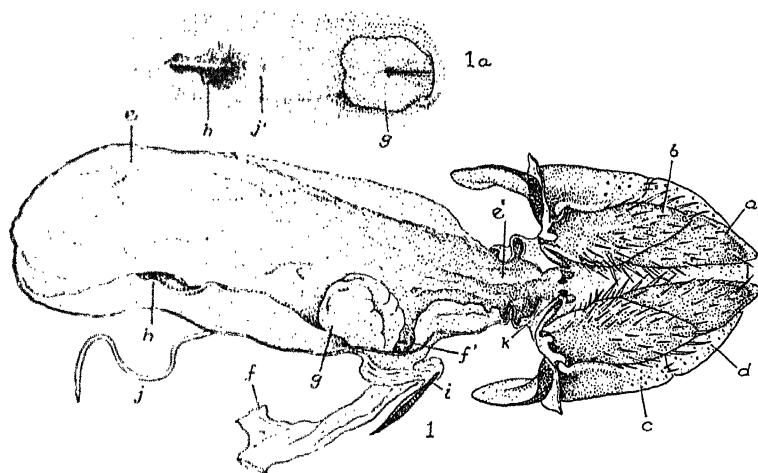




PLATE 71

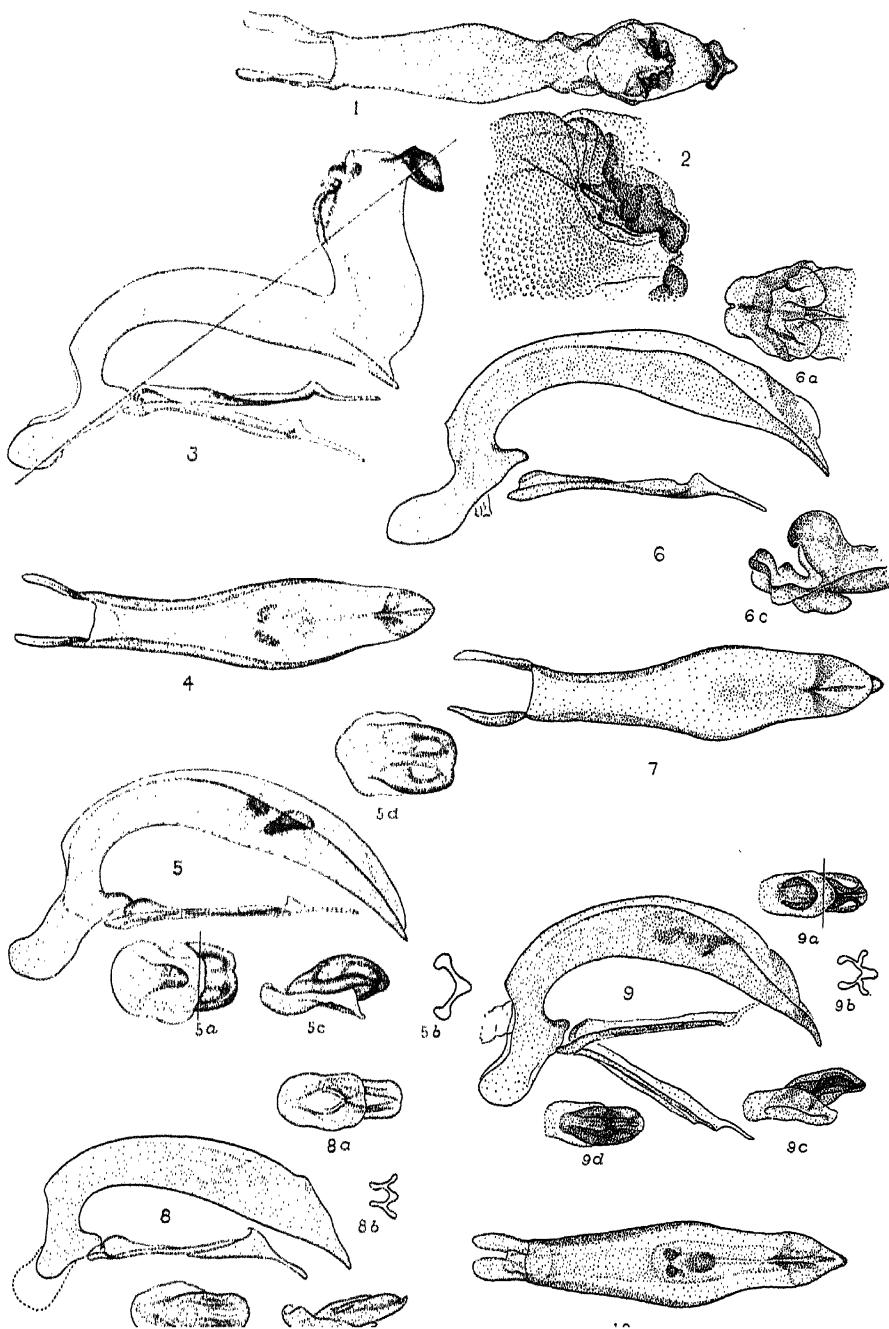




PLATE 72

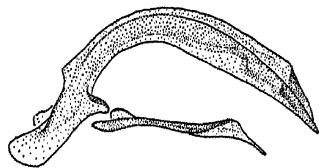
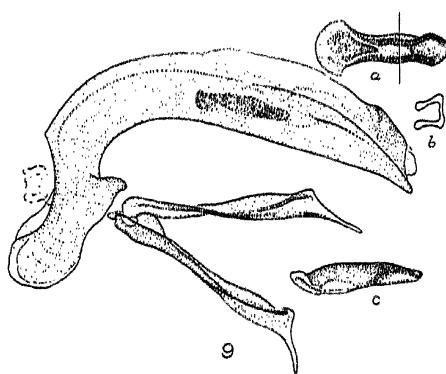
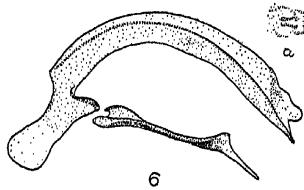
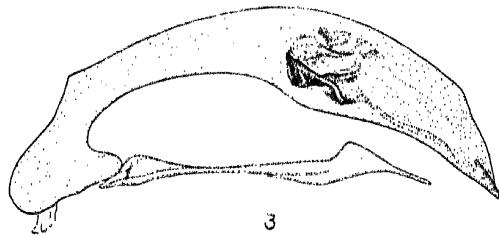
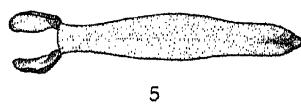
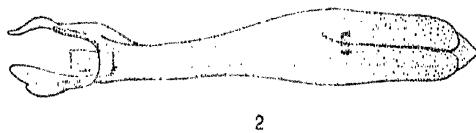
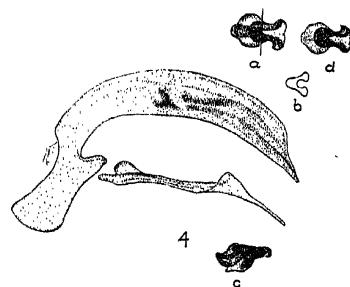
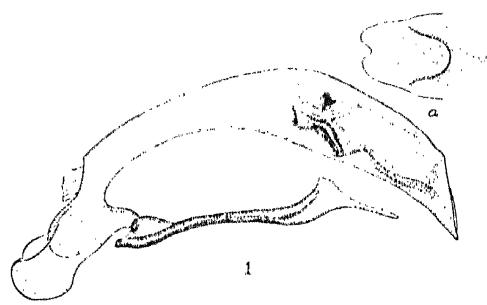
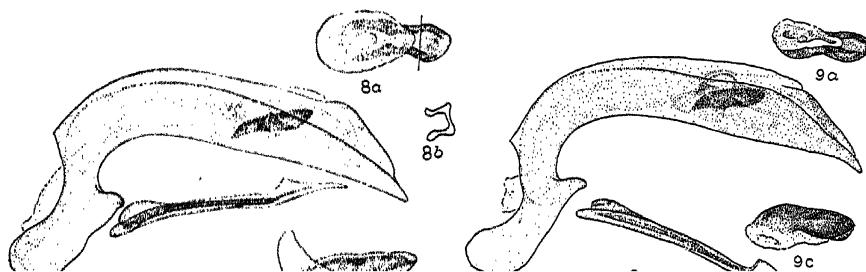
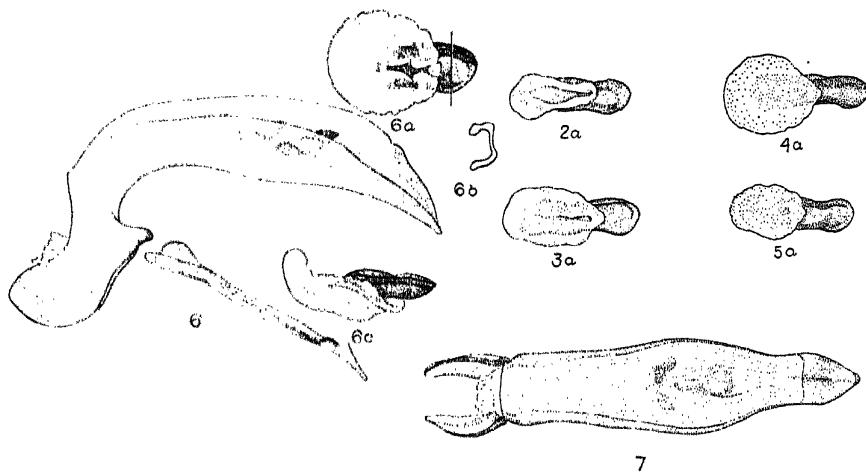
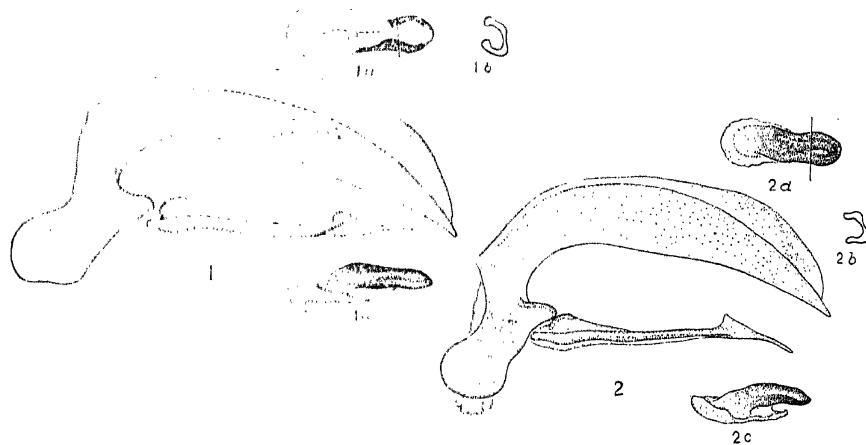




PLATE 73





I. A. R. I. 75.

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